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J. F. KELLY, Editor

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ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

CONVENTION—EXPOSITION

JUNE 16-17-18-19-20, 1930

BUFFALO, NEW YORK

Technical Sessions, Statler Hotel, Iron & Steel Exposition—Broadway Auditorium

MONDAY, JUNE 16th

9:00 A. M.—Registration
9:30 A. M.—Business Session.
9:45 A. M.—Electric Developments in the Iron and Steel Industry.
10:15 A. M.—Shop Practices in the Iron and Steel Industry.
11:00 A. M.—Steel Mill Lighting Problems.
12:30 P. M.—General Luncheon, Safety Engineering Division.
1:15 P. M.—Electrical Practices in Russia.
1:45 P. M.—Should Universities and Colleges Establish a Safety Engineering Course in Their Curriculum?
7:00 P. M.—Formal Opening of the Iron and Steel Exposition, Broadway Auditorium.
9:00 P. M.—Informal Reception and Entertainment.

TUESDAY, JUNE 17th

9:30 A. M.—The Theory of Rolling Plastic Material.
10:45 A. M.—A Rolling Mill Analysis.
11:30 A. M.—Welding Rods and Wire.
12:30 P. M.—General Luncheon—Electric Engineering Division.
1:15 P. M.—Experiences with Electrically Operated Skip Hoists in China.
1:45 P. M.—A Moving Picture from the Raw Materials to Finished Product.

WEDNESDAY, JUNE 18th

ELECTRIC ENGINEERING DIVISION

9:30 A. M.—Anti-Friction Bearings for Mill Type Motors, General Purpose Motors, Electric Overhead Traveling Cranes, Roll Necks.
10:30 A. M.—Special Feature: Anti-Friction Bearings for Roll Necks, to be Discussed by Steel Mill Executives and Engineers, Also Anti-Friction Bearing Manufacturers.

COMBUSTION ENGINEERING DIVISION

9:30 A. M.—Recent Developments in Heating Furnace Design.
10:30 A. M.—Symposium: Open Hearth Furnace Control.
11:30 A. M.—The Use of Mixed Gases in Iron and Steel Plants.

WIRE AND WIRE PRODUCTS DIVISION

9:30 A. M.—Galvanizing.
10:15 A. M.—Methods of Drawing Rods and the European Rod Drawing Processes.
11:15 A. M.—The Latest Developments in Wire Drawing, Wire Forming Machinery.
11:45 A. M.—A Moving Picture, the Making of Steel Wire.
12:00 Noon—A Moving Picture, the Story of Monel Metal.

THURSDAY, JUNE 19th

9:30 A. M.—Specifications for Electric Overhead Traveling Cranes.
10:45 A. M.—Electrical Installations at the Lackawanna Plant of the Bethlehem Steel Co.
6:30 P. M.—Formal Reception, Members, Guests, Exhibitors.

FRIDAY, JUNE 20th

9:30 A. M.—Inspection Trip, Lackawanna Plant, Bethlehem Steel Co., Lackawanna, N. Y. (Guests of Mr. T. Burns, General Manager). Make Reservations Early.

IRON AND STEEL EXPOSITION—BROADWAY AUDITORIUM

50,000 Square Feet Devoted to All the Latest Types of Apparatus Used in Producing Iron and Steel.

EXPOSITION HOURS

Monday, 1:30 to 5:30—7:00 to 9:30 P. M.
Tuesday, 1:30 to 5:30—Not Open in Evening.
Wednesday, 1:30 to 5:30—7:00 to 9:30 P. M.
Thursday, 1:30 to 5:30—Not Open in Evening.
Friday, 1:30 to 5:30—7:00 to 10:00 P. M.

Special Features: Welding Pipe Electrically, Wire Drawing and Wire Making.

The Iron and Steel Engineer is the Only Periodical That Will Carry All the News of the Convention.

ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

INSPECTION TRIP

LACKAWANNA PLANT

BETHLEHEM STEEL COMPANY LACKAWANNA, N. Y.

FRIDAY, JUNE 20th

Members, Guests and Exhibitors invited. Trip must be made in Special Busses which will leave the Main Entrance, Hotel Statler, Buffalo, N. Y. at 9:30 A. M. Reservations must be made for this trip at the Registration Desk, Main Lobby of the Hotel Statler, June 16, 17 and 18.

SCHEDULE AND ROUTE A. I. & S. E. E.
INSPECTION TRIP

9:30 A. M.—Leave Hotel Statler.

10:00 A. M.—Arrive at Plant.

10:15 A. M.—No. 2 Power House.

10:45 A. M.—Entrain.

10:50 A. M.—Blast Furnaces.

11:15 A. M.—Coke Oven Plant.
Complete Automatic Sub-Station.

11:45 A. M.—Entrain S. E. Coke Plant.

12:00 Noon—54" Blooming Mill Motor Room, No. 12 and No. 15 Mill Motor Rooms, No. 14 Mill 18", 14" Bar and Structural Mill.

1:00 P. M.—Luncheon (Guests of Mr. T. Burns, General Manager, Lackawanna Plant, Bethlehem Steel Company.)

1:30 P. M.—No. 5 Mill 48" Universal Plate Mill.

1:45 P. M.—No. 1 Open Hearth.

2:00 P. M.—No. 10 Mill 8", 10" Merchant Mill.

2:05 P. M.—No. 7 Mill Motor Room.

2:15 P. M.—No. 1 Rail Mill.

3:00 P. M.—Entrain.

3:15 P. M.—No. 3 Power House (Purchased Power Sub-Station.)

4:00 P. M.—Busses.

4:30 P. M.—Iron and Steel Exposition.

5:00 P. M.—Grand Drawing and Awarding of Prizes for Attendance at the Iron and Steel Exposition.

The Lackawanna Plant of the Bethlehem Steel Company is equipped to manufacture the following materials: Pig Iron, Ingots, Billets, Blooms, Slabs, Sheet Bars, Tie Plates, Heavy and Light Rails, Splice Bars, Structural Shapes, Sheared and Universal Plates, Merchant Bars, Concrete Reinforcing Bars, Sheet Piling and Fabricated Structural Material.

The steel and iron production equipment consists of 2 Open Hearth Plants, No. 1 Open Hearth has 14 100-ton stationary furnaces and No. 2 Open Hearth has 2 200-ton tilting and 8 100-ton stationary furnaces. Also, 4 10-ton converters. The capacity of the Open Hearth and Bessemer Departments are 2,000,000 gross tons per year. There are 7 blast furnaces, one of which is rated at 1,000 tons, 2 at 800 tons, one at 600 tons and 3 at 500 tons. The total capacity of Bessemer and Basic Pig Iron is 1,440,000 gross tons a year.

One of the high spots in the electrification of this plant is twelve reversing mill motors —one-eighth of the total reversing mill motors installed in the United States and Canada.

The total HP in reversing mill motors is 56,000.

The June Convention Issue of the Iron and Steel Engineer will carry all the news of the Convention.

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Comparative Value of Fuels in Steel Mills

By H. V. FLAGG†

A comparison of fuel values involves two lines of attack. The first is the thermal comparison of the heat available in the fuels to be considered, and after that comparison is made and a basis for comparison of the fuels from the thermal standpoint is reached, the second is to work out the use comparisons so that the effect of these factors also may be taken into account and the final equivalent values set up.

With some fuels there is an expense for preparation: coal-handling and ash disposal, and other such factors. There are expenses for maintenance of furnaces and other items that have to be evaluated and credited or debited to the value of the fuel after the thermal equivalents are reached. These latter evaluations depend very much on the application.

What I have undertaken to do here today is to present a method for evaluation of the thermal value of fuels, I want to make one reservation at the outset, which is that this paper is to apply only to a method for working out the thermal value of fuels.

From that basis, then, the title of this paper is somewhat of a misnomer. "Comparative values of fuels" is a broad statement that should include the whole comparison. Probably if we were to call this particular paper, "Comparisons of thermal value of fuels," it would be more nearly what the paper really is.

The truest basis available for the comparison of fuel values lies in the amount of heat carried out in the flue gases. The difference between the potential heat input in a unit amount of fuel and the heat in the flue gases from that amount of fuel leaving the furnace is the amount of heat given up to the furnace.

The data necessary for the evaluation of this difference are as follows:

1. Ultimate analyses of solid fuels.
2. Analyses of ashes from solid fuels.
3. Volumetric analyses of gaseous fuels.
4. Gross or 'higher' heating values of fuels.
5. Temperature of gaseous fuel and of combustion air if preheated.
6. Analyses of flue gases leaving the furnace.
7. Temperature of flue gases at point of sampling.

Since comparisons of fuel values are usually made for a specific application, furnace losses from radiation and infiltration may be neglected as they are the same for all fuels. Furnace refinements which make possible better utilization of fuel need not be considered so long as they hold good for all the fuels being considered. The heat in air and fuel at atmospheric temperature is so nearly the same for comparable amounts of fuel that it can be disregarded. The amount of moisture in the combustion air varies so much with atmospheric conditions that any arbitrary assumption for this factor merely introduces an added complication. In any event, the moisture in the combustion air for comparable amounts of fuels will be so nearly the same that it also may be disregarded.

Comparisons of fuel values made on the basis of available heat before flue gas losses holds good for all steel mill applications within limits. For an application where the atmosphere is oxidizing and where the time element permits of heat transfer over a large heating surface, as in a boiler furnace, the problem becomes a simple one. In an open hearth furnace which requires an extremely high heat transfer in a relatively short space and in a very short time, another factor enters which is not taken into account by this method of comparison, but which does have a vital effect on furnace performance and on fuel economy. This influence depends on the heat transfer characteristics of the flame from the fuel under consideration at open hearth conditions. Fuels having similar flame characteristics can be compared successfully by this method. For applications such as sheet normalizing where the atmosphere must be consistently reducing, the loss due to incomplete combustion must be taken into account since the extent of this loss varies considerably with different fuels. The flame characteristics also have some effect on fuel economy in this application.

The development of equivalent values for the usual steel mill fuels for even the more important applications would be too pretentious an undertaking for a single paper and for the purpose of this presentation one example will suffice. The boiler furnace application will be used and the fuels considered will be as follows

A. West Virginia lump coal.
B. Nut and slack grade of the same coal.
C. Coke breeze.
D. Washed blast furnace gas.
E. Raw blast furnace gas.
F. Coke oven gas.

For purposes of comparison, the calculations will be based on 1,000,000 BTU of fuel supplied, figured on gross heating value. The pound mol unit will be used in order to simplify calculations. The equations for mean molal specific heats of gases above 60°F used, are those developed by Haslam and Russel in their treatise on Fuels and Their Combustion, and are as follows:

$$CO_2, SO_2 \quad MC_p = 7.00 + 0.0039\,T - 0.000000574\,T^2$$
$$N_2, O_2, H_2, CO \quad MC_p = 6.50 + 0.00055\,T$$
$$H_2O \quad MC_p = 8.81 - 0.00105\,T + 0.000000685\,T^2$$

Where MC_p is the amount of heat necessary to raise 1 mol gas 1°F between T (absolute)

†Asst. Comb. Engr., American Rolling Mill Company, Middletown, Ohio.

*Presented before Association of Iron & Steel Electrical Engineers, February 7, 1930, Youngstown, Ohio.

1. Fuel analyses used are as follows

	A Lump Coal	B Nut and Slack Coal	C Coke Breeze		D Blast Furnace Gas Washed	E Blast Furnace Gas Raw	F Coke Oven Gas
C	74.20	68.50	75.12	CO_2	13.5	13.5	2.5
O_2	8.16	7.49	.....	O_2	0.1	0.1	0.2
H_2	5.37	4.99	.....	C_2H_4	.....	.....	2.5
N_2	1.22	1.12	.....	CO	26.4	26.4	6.0
S	0.85	0.88	.....	H_2	1.8	1.8	52.0
Ash	7.20	12.85	10.17	CH_4	0.1	0.1	32.0
H_2O	3.00	4.25	14.71	N_2	58.1	58.1	4.8
BTU per Lb.	13,777	12,300	11,000	BTU/CuFt.	97.6	97.6	554
C in ashes	17.00	21.00	15.00	H_2 Lb/CuFt.	.002177	.00252	.00146
2. Quantity of fuel per million (MM) BTU	72.6 lbs.	81.3 lbs.	91.0 lbs.		10,250 CuFt.	10,250 CuFt.	1,805 CuFt.
3. Flue gas analyses							
CO_2	13.0	12.5	14.0		23.3	23.3	9.6
O_2	6.4	6.9	6.0		1.2	1.2	2.0
N_2	80.6	80.6	80.0		75.5	75.5	88.4
Temperature of flue gases	600°F	600°F	600°F		640°F	640°F	600°F
4. Lbs. Carbon per MM BTU — Lbs. fuel per MM BTU x % carbon	54.0	55.6	68.3				
5. Lbs. Carbon in Ashes — Lbs. fuel per MM BTU x % ash x % C in ashes ÷ % ash in ashes	1.07	2.78	1.63				
6. Lbs. Carbon in Flue Gases per MM BTU — Item (4) — Item (5)	52.93	52.82	66.67				
7. Mols Carbon in Flue Gases — Item (6) ÷ 12; Mols Carbon in gas per MM BTU	4.411	4.402	5.556		10.8	10.8	2.16
8. Mols DRY Flue Gases per MM BTU of Fuel — Item (7) ÷ % CO_2 in Flue Gases x 100	33.95	35.20	39.70		46.40	46.40	22.50
9. Mols CO_2 and $O_2 + N_2$, Item (8) x % in Flue Gases ÷ 100							
CO_2	4.41	4.40	5.56		10.80	10.80	2.16
$O_2 + N_2$	29.54	30.80	34.14		35.60	35.60	20.34
9A. Air Used per MM BTU: Mols N_2 in flue gases—Mols N_2 in fuel ÷ 0.79 × 29 lbs. or 380 Cu. ft.							
Lbs. air	1,003	1,040	1166		710	710	722
Cuft air at 60°F	13,150	13,630	15,275		9,310	9,310	9,460
10. Moisture from Fuel per MM BTU — Lbs. or Cuft. per MM BTU x Lbs. H_2O per Lb. or Cuft.							
Lbs.	2.16	3.46	13.38		22.31	25.80	2.64
Mols	0.12	0.192	0.748		1.24	1.435	0.147
11. Moisture from Combustion of H_2 — Solid Fuels, Lbs. Fuel x % H_2 x 9 ÷ 100 Gaseous Fuels, Cuft. Gas per MM BTU x Cuft. H_2 per Cuft. Gas x .00531 x 9							
Lbs.	35.1	36.45	.....		9.80	9.80	104.33
Mols	1.95	2.03	.....		0.54	0.54	5.80
12. Total Moisture in Flue Gases — Item (10) + (11)							
Lbs.	37.26	39.91	13.38		32.11	35.60	106.97
Mols	2.07	2.222	0.743		1.78	1.975	5.947
13. Sensible and Latent Heat in Flue Gases — Mols gas x MC_p x (T — 60)							
CO_2	23,400	23,300	29,400		60,500	60,500	11,400
$O_2 + N_2$	112,000	117,000	129,700		146,000	146,000	77,200
H_2O sensible	9,500	10,200	3,400		6,100	7,000	27,400
H_2O latent	39,400	42,200	14,100		34,000	37,600	113,000
Total	184,300	192,700	176,600		246,600	251,100	299,000
14. Sensible Heat in Raw Blast Furnace Gas at 400°F, Mols Gas = 10,250 ÷ 380 = 27 Mols						70,400	
15. Heat Available per MM BTU, 1,000,000 — Item (14) — Item (13)	815,700	807,300	823,400		753,400	819,300	771,000
16. BTU Available per Lb. or CuFt of Fuel — Item (15) ÷ Item (2)	11,240	9,940	9,050		73.5	79.9	427
17. Fuel Equivalents on the Basis of 2,000 Lbs. Lump Coal — from Ratios set up in (15)	2000 lbs.	2260 lbs.	2480 lbs.		306,000 CuFt	281,000 CuFt	52,460 CuFt
18. Equivalent Fuel Values Based on Lump Coal at $3.50 per ton	$3.50	$3.10	$2.82		1.143c Mcuft	1.245c Mcuft	6.67c Mcuft

It should not be necessary to emphasize that these comparisons hold true for the fuel analyses used only and likewise only for the combustion conditions indicated by the flue gas analyses used. The material in this paper is not meant as a brief for any particular fuel or system of combustion, but is

presented solely to indicate a usable and useful method of attack for problems involving fuel comparisons. This device should prove useful for calculating equivalent values of blast furnace gas, coke oven gas, coke breeze, or coke oven tar, when credits for these by-products, based on the prevailing price for coal, must be established. The feasibility of capital expenditures for new equipment for saving waste heat can be determined quite accurately by use of this method. The effect of over-ventilation on fuel economy may readily be calculated.

No claim for originality is made for this presentation since all the principles used may be found in the literature and are in daily use. It is hoped that the plan of making the calculations on a comparable basis may simplify to some extent the use of the amount of heat in the waste gases as a criterion for fuel comparisons.

For purposes of comparison, the basic calculation is on a million b.t.u. of fuel supplied, figured on gross heating value. The pound mol unit is used to simplify calculations. I don't know whether it is necessary to say what we mean by "pound mol unit" before this group. I expect every one understands it. It is simply that the pound mol is the unit for both volume and weight, 380 cubic foot at 60° and in weight a molecular weight of the gas under consideration in pounds. This makes a very convenient unit for combustion calculation.

(Mr. Flagg read the figures appearing on page 2 of his prepared paper.)

Of course those figures are theoretical comparisons, and the practical considerations must be taken into account after you have made these comparisons, and it should not be necessary to emphasize that these comparisons hold true for the fuel analyses used only and likewise only for the combustion conditions indicated by the flue gas analyses used. In respect to this item, I might say that these fuel gas analyses I have used are largely assumed. Some of them I knew were possible and practical, and I felt that I could use them. Some of the others I didn't have sufficient information on and I had to calculate theoretical flue gas analyses, and assume the excess air that would be practical.

The material in this paper is not meant as a brief for any particular fuel or system of combustion but is presented solely to indicate a usable and useful method of attack for problems involving fuel comparisons. This device should prove useful for calculating equivalent values of blast furnace gas, coke oven gas, coke breeze, or coke oven tar, when credits for these by-products, based on the prevailing price for coal, must be established. The feasibility of capital expenditures for new equipment for saving waste heat can be dtermined quite accurately by use of this method. The effect of over-ventilation on fuel economy may readily be calculated.

No claim for originality is made for this presentation since all the principles used may be found in literature in daily use. It is hoped that the plan of making the calculations on a comparable basis may simplify to some extent the use of the amount of heat in the waste gases as a criterion for fuel comparisons.

WIRE DAY

WEDNESDAY, JUNE 18, 1930

AT THE IRON AND STEEL EXPOSITION TO BE HELD AT BUFFALO, N. Y., JUNE 16 TO 20, INCLUSIVE.

This is an Open Invitation for You to Visit This Show—See the Exhibits and Attend the Technical Sessions!

COME AND EXCHANGE IDEAS! SEE HOW THE OTHER FELLOW DOES IT!

See the Latest Improved Machines in Operation.

Hear Kenneth Lewis, Vice President of Morgan Construction Company, Tell About Processes and Things Which "Can't Be Done" As Being Actually Accomplished in European Wire Mills.

Come to the Technical Sessions and Learn—Look Over This Interesting Program—

Wire Section Technical Session, Wednesday, June 18, 1930

A paper by Kenneth B. Lewis, Vice-President of the Morgan Construction Company, Worcester, Mass., on the subject of drawing wire rods. Mr. Lewis returned from a tour of inspection of European wire mills on April 8th, and will present a very interesting story about the differences in practices existing between European and American mills.
A paper by Clarence S. Arms, consulting engineer on wire drawing equipment for Sleeper & Hartley, Inc., Worcester, Mass., who will present a paper on the subject "Recent Developments in Wire Drawing and Wire Forming Machinery."
A paper on "Galvanizing" by W. H. Spowers, Jr., consulting engineer on galvanizing and associate editor of Wire & Wire Products.
A motion picture entitled "The Making of Steel & Steel Wire" with an informative talk by a representative of the American Steel & Wire Co.
A motion picture on "Monel Metal and Its Uses" with a talk by a representative of the International Nickel Company.
You are invited to come, learn and participate!

Technical Sessions *Statler Hotel, Buffalo, N. Y.*

Come to Buffalo, June 16-20

Comparative Value of Fuels in Steel Mills

By H. V. FLAGG

Discussion

Discussed by

M. J. Conway, Fuel Engineer, Lukens Steel Company, Coatesville, Pa.

J. L. Miller, Steam Engineer, Carnegie Steel Company, Youngstown, Ohio.

J. B. Crane, District Manager, International Combustion Engineering Company, Pittsburgh, Pa.

F. E. Leahy, Combustion Engineer, Youngstown Sheet & Tube Company, Youngstown, Ohio.

J. M. Spitzglass, Vice-President, Republic Flow Meters Company, Chicago, Ill.

H. J. Freyn, President, Freyn Engineering Company, Chicago, Ill.

H. V. Flagg, Assistant Combustion Engineer, American Rolling Mills Company, Middleton, Ohio.

F. F. Foss, Assistant to the President, Wheeling Steel Corporation, Wheeling, W. Va.

J. F. Shadgen, Smoot Engineering Corporation, New York, N. Y.

George S. Hendrickson, Sales Engineer, Republic Flow Meters Company, Chicago, Ill.

Harry Dobrin, Consulting Fuel Engineer, Pittsburgh, Penna.

M. J. Conway: Mr. Flagg has given us an excellent paper on a little-used method of fuel comparison, which may be the beginning of a new way of comparing fuel values. I wish he had extended it further and into liquid fuel so that we would have a much larger picture. However, he has done a good job with the fuels he has handled.

F. F. Foss: The two papers which we heard today, Mr. Spitzglass' and Mr. Flagg's papers, brought to me some reminiscences from my college days.

A student was examined in mathematics. He came to the blackboard and got a question in Newtonian binomial theorem. He has put a set of figures on the blackboard and then, after some hesitation, wiped all out. Professor looked at him, he wrote again another set of figures, and also wiped them out; then suddenly he wrote an answer and exclaimed "Professor, here's the result. Isn't it correct?"

Professor said, "Yes, the result is correct, but how did you arrive at that?"

"Oh, isn't the result what you want? The result is right, so never mind how did I arrive at the answer."

Something analogical happens very often to fuel engineers, who, after having made their meter readings with a preciseness of one-half of 1 per cent, bring total figures to the cost accountant, and say, "We can't account for one million b.t.u. or one million cubic feet of gas and evidently such and such department has to assume this difference."

With this story I had in mind to draw your attention to the fact that as long as we do not have in our plants a rounded system, which checks the input of fuel—with its total outgo properly distributed, we can't go very far with calculations of losses to the extent of 1.5 per cent. Usual practice shows that actual spread between debits and credits of the b.t.u., when we try to balance out fuel received and fuel used, very often is 10 times larger than the mistakes in meter readings.

Since consumption of blast furnace or coke oven gas by such apparatuses, as blast furnace stoves, regenerative chambers of coke ovens, waste gas boilers, and heating furnaces, is not carefully checked, and in most cases is calculated on assumed coefficients, it seems to me that before making any use of highly scientific calculation of losses—fuel engineers, first of all, should start to measure all gas in the plant—wherever it goes to or wherever it comes from.

Only then, will it be possible to make a semblance of a complete thermal balance sheet of every metallurgical unit using fuel. That is the main point. Next step after that, of course, will be the preciseness in meter readings—as it is already practiced by most advanced fuel engineers.

Mr. Flagg's paper is, without doubt, an excellent paper, good calculations. It is not a new way, however, but still it is a good way to calculate the efficiency of different fuels. As he, himself, has already mentioned, the title of his paper is a kind of misnomer. Actually the paper doesn't show the comparative value of different fuels in different conditions, as it might be expected from its title.

It looks to me, that in calculation of the value of any fuel, we must take into consideration the process by which this fuel was received, and the process for which it should be used—having in mind highest possible efficiency. We know, for instance, that gas fuel has very high value for industrial purposes in general, but if you have to use it for a blast furnace, its value would be very low.

So, to my mind, the main point in evaluating any fuel is to find out an index, so to speak, which will show highest efficiency of this fuel in optimum condition of its production and utilization.

Take, for instance, blast furnace gas. What is the best place for this gas in steel plant? Whether

it has to be used under boilers where, by the way, at the present time in very many plants it is used, or whether it is in the open hearth furnaces, or in the reheating furnaces, or for heating of coke ovens? The same thing is true of the coke oven gas. We know that lots of coke oven gas is burned under boilers. Is that correct or not, and whether this gas in such place gives the real "thermal value" compared with other uses?

About three years ago, calculations were made by which it was attempted to answer the question in reference to the evaluation of blast furnace gas—based on 1000 b.t.u. of gas and coal. If we use blast furnace gas in gas engines, with the electric generator attached, without waste heat boiler, the value of gas in this unit will be from 1.3 to 1.4 of the respective 1000 b.t.u. of coal; but if you have a gas engine for electric generation with waste heat boilers, the value of blast furnace gas will be raised to 1.5-1.6. If you turn blast furnace gas into the gas-blowing engine without waste heat boiler, its efficiency will be only 1.0 to 1.3 over coal. In case gas blowers will have waste heat boilers, the ratio will go up to 1.5. In heating of by-product coke ovens the value of blast furnace gas is from 1.3 to 1.8. It seems that best utilization of blast furnace gas can be achieved under by-product coke oven.

Open hearth furnaces, when blast furnace gas is mixed with coke oven gas, give 1.5 to 1.8 ratio, and reheating or welding furnaces give from 1.0 to 1.5. Under the boilers, if the supply of blast furnace gas is constant, value 1.0 to 1.4 is received, and if gas is used intermittently, it is only 0.9 to 1.1 in comparison with coal.

Such an analogical problem must be solved, when we have in mind to establish the real value of different fuels in given conditions.

In brief, it looks to me that Mr. Flagg's paper is only an introduction to the complete evaluation of economic values of gas or any kind of fuel. Besides theoretical computation of thermo-chemical results, consumption of human effort, capital engaged and efficiency of machines, furnaces and other appliances in producing of thermal energy and in using of fuel in given conditions, must be taken into consideration, and only then will it be possible to get more or less correct evaluation of different fuels used in steel plants.

J. L. Miller: No, Mr .Conway, I don't believe I have anything at all to add. I am very much interested in this thing. We have done considerable along the line of what Dr. Foss has just mentioned, and I believe that Dr. Foss also gave me personally some instructions along that line sometime past. I really got my instructions in studying that from him, so I feel somewhat as he does.

I am now wondering about the values between blast furnace gas and producer gas.

J. B. Crane: The only thing I can add to it is along the same lines as the Doctor here, that this is the beginning of the study—that you have to consider the use and the way it can be used. For instance, the boiler to deliver 150 pounds of steam with coal, and an efficiency of 85 per cent, will only deliver 125,000 pounds of steam with blast furnace gas at an efficiency of 83 per cent.

About fifteen years ago I had occasion to build a plant up in Minnesota to use wood refuse from a lumber mill which had been burning it in a refuse burner. In getting the value of the fuel, the lumber company called in a firm of consulting engineers. They analysed the wood fuel, and found it had a heating value dry of about 8,000 b.t.u., against the coal which was available in that territory with 13,500 b.t.u. The coal cost $4 a ton. The wood refuse contained 46 per cent moisture, so they reported to the lumber company that we ought to pay $1.02 a ton for this wood refuse.

We went down to see the engineers and asked them how they were going to burn this wood refuse. They were going to burn it under boilers.

We asked what rating we were going to get under boilers. They went to work and made some figures, and decided they would get about 100 per cent.

What could we get with coal? Well, we could get 150 to 200 per cent rating with coal. Consequently we had to put in more coal to burn wood refuse.

We asked them if the lumber company was going to run continuously, or if there might be chances that they would shut down over Sunday or something of that kind. Well, they went into it, and found out that there might be several times when they would shut down and when they couldn't guarantee us wood refuse, but there was enough wood refuse so it could be stored. On that basis we finally worked out that it was worth about 65 cents a ton to us, that is, if it was just equivalent we would rather have the coal plant because we could store coal, and so forth, but we took it on the basis that we would be able to store the wood refuse to carry us over the low period.

We found the wood refuse didn't store so well. If it laid in a pile for any length of time, it got moldy and wouldn't burn satisfactorily; so consequently we had to carry coal in storage to carry us over the period when the mill wasn't running. That meant we had to put in stokers to operate the boiler when the wood refuse wasn't available and it actually worked out that the wood refuse was worth about 40 cents a ton to us.

F. E. Leahy: The basis for comparing the relative values of fuels as proposed by Mr. Flagg is very interesting. In the application of various fuels to the same process, it is often noticed that the results obtained vary over quite a range, and to use a given installation that may have been designed primarily for a particular fuel will often result in a variable efficiency, depending on the kind of fuel used. For this reason, as pointed out in this paper, the heating value of the fuel as determined by a calorimeter is not a true measure of the replacement value.

A very interesting part of this discussion is referred to in the remarks on flame characteristics, and the complete study of the comparative values of fuels will eventually take this characteristic into consideration for each particular application. The demands now being made on improved quality of output have been responsible for calling to the attention of various observers, particular features in certain fuels that make them more attractive for a given operation than other fuels.

I think the plan as outlined in this paper is worthy of some study, and it will be interesting to

note how this subject will be developed, through such a plan as this, into a rational plan for determining the comparative values of the various fuels available.

J. M. Spitzglass: Mr. Flagg's paper is just the kind of material I live on, so you won't criticize me for getting up again and saying something about it. However, my main reason for rising is to say something about the second speaker first. I was wondering whether when he put us together on the blackboard, he meant to praise us or to blame us. Really I couldn't see the point immediately. Then I thought, well, it really doesn't make any difference.

A German writer once said, when I talk to you I don't care whether you throw rotten eggs at me or flowers so long as you do something. If you don't say anything, I know I am doomed. So it really doesn't matter, but if it is a complaint, of course, you understand that it isn't my fault. I was perfect. I immediately told you that it was something new and that you must believe it, so you can't say I am to blame for not proving the figures to the satisfaction of the professor.

I believe Mr. Flagg spoilt his. He told you that there isn't anything new in his paper. It was new to me and I believe it is new to many others.

The only thing I would suggest is that the heading be changed. To be sure it isn't a comparative value of fuel. It is just a basis, a theoretical basis, or, you may say, a theoretical method of forming a basis to give the value of fuel, because the value of fuel is not exactly the b.t.u., but amount that can be put to useful work in the given case.

In order to determine the useful work, you must first get the theoretical value as a basis. We can't blame Mr. Flagg, because that is what Carnot and Rankine did. They determined first the amount of heat that is available. That is the limit, and Mr. Flagg gave us the limit values, so to say, of the fuel. The procedures first to determine the limitations of the value in the fuel, or the theoretical value, and then we proceed to the practical application.

H. J. Freyn: I have listened with keen interest to Mr. Flagg's splendid paper and to the able discussions of Messrs. Foss and Spitzglass. The latter particularly has expressed the very thoughts which occurred to me.

Limiting my remarks to the interesting figures in Mr. Flagg's paper relative to the value of blast furnace gas, I can imagine the impression that an executive in a steel company might receive in reading Mr. Flagg's paper unless the statements are qualified. He might jump at the conclusion that on the basis of $3.50 for lump coal, washed gas being worth 1.143 and raw gas 1.425, the latter is a much more valuable fuel than the former.

Many of you who have had experience in the use of blast furnace gas know that the question whether or not blast furnace gas should be washed, is as old as its application in the iron and steel industry. It is also known that this question cannot be answered categorically. The practical relative value of "washed" or "raw" blast furnace gas depends largely on the use to which it is put; in other words, on the apparatus or mechanism or process in which it is to be utilized.

I remember that in 1899 when blast furnace gas was first employed in gas engines, it was attempted to use it in its raw or semi-cleaned condition. Experiments on a small scale seemed to indicate that this was possible, but when larger units were built, it was soon found that for mechanical and practical reasons only highly purified blast furnace gas would answer the purpose.

It is true that by washing a certain percentage of the thermal value of blast furnace gas is sacrified, but this is necessary in the majority of present-day applications for reasons similar to those which resulted in the development of the art of gas cleaning originally primarily for gas engine use.

I thoroughly agree with the other speakers that Mr. Flagg's paper offers a very valuable basis—a sort of yardstick—for comparisons, but one that must be applied with caution.

M. J. Conway: Mr. Flagg, do you want to answer some of the questions that have already arisen, or do you prefer to wait until everybody has discussed the paper?

H. V. Flagg: I don't know that there are any particular questions for me to answer.

M. J. Conway: Mr. Leahy asked regarding the flame characteristics.

H. V. Flagg: My whole idea in presenting this paper was just exactly what has come out of it. I hadn't any intention, of course, of forcing onto you a standard net of values for fuels. I hope I know more than to have attempted to do anything of the sort. I have had questions come up ever since I have had anything to do with fuels, such as how much coke oven gas would be required to replace so many pounds of coal gasified in an open hearth. After the replacement was made and the actual figures were obtained, they didn't check up, the calculations, and I have seen that happen many times for as many applications.

I have heard it said, "Coke oven gas is worth 15 cents a thousand cubic feet for a certain application," have made the replacement on this basis, and then finally have found that the fuel cost on this particular operation has increased. In other words, coke oven gas was not worth 15 cents compared to the original fuel and a comparison on the basis of available heat would have shown it so in the first place.

As far as the flame characteristic is concerned, there is a beautiful field for a paper long enough to keep several meetings busy. We had a fine article on this subject last spring, and I have since seen some things myself that bear out the fact that the flame characteristic does have a considerable effect on the value of the fuel. I have seen this method of comparison fail in the open hearth simply because of the fact that the flame characteristics of a certain fuel were such that it was impossible to get the necessary heat transfer to develop the temperature in the bath that was necessary. It wasn't a question of how many b.t.u. you put in or took out. It was a question of poking enough heat into one particular spot to develop the temperature necessary for the working of the bath. So there is no doubt in the world but that the flame has a vital bearing on the comparative value of the fuel.

Was Mr. Miller's question as to the comparative

values of blast furnace gas and producer gas a request for concrete values?

J. L. Miller: Yes.

H. V. Flagg: I haven't an answer to that in a concrete way, but I do believe that you could approach an answer to it by using some such device as we have shown in the application here today. I have seen worked out some examples of the use of this method that gave results surprisingly close to those obtained from actual test data. I have seen it in the open hearth, in normalizing practice, and on heating furnace practice. I would just like to suggest that by using some such attack you can come very close to the answer to the problem as far as the values of the fuels are concerned.

The figures on the relative values of the different fuels given us by Mr. Foss are another example of what I said a moment ago: I was hoping to bring out in this paper data that would start discussion and it certainly was interesting to have those comparison figures given us.

J. L. Miller: The reason why I mentioned that is that there are two rather large steel concerns today that I believe have replaced their producer gas-fired pits with blast furnace gas, and I thought possibly somebody here might be connected with one of the concerns and might give us some little idea of the practical end of the replacement.

H. V. Flagg: I am not familiar with them myself.

M. J. Conway: Is there any one here connected with steel plants using blast furnace gas in soaking pits, who would like to give Mr. Miller an answer to his question as to the procedure used in replacing producer gas with blast furnace gas?

There was no one present to discuss the subject.

F. F. Foss: Permit me to answer Mr. Spitzglass. Mr. Spitzglass is too modest and didn't want to take the prize when it was given to him. In telling the story about college student and in making these remarks I did not have in mind to throw any reflection on the excellent method of calculations, which Mr. Spitzglass has presented. I wanted only to draw a parallel, that in practical work—fuel engineers are confronted very often with results, which have been arrived at without any calculations. You are making your graphs and all kinds of curves, calculating 1.5 per cent of losses, "check it and double check," after what cost accountant says to you: "Here's the figure of gas delivered for this month. It is on one million cubic feet above your figures, and such and such department has to take the difference;" you agree to that, whether there is 1½ per cent correction in the calculation, or not. That is all.

J. F. Shadgen: I want to call your attention to one point which has not been brought out in Mr. Flagg's able paper: The analyses of the flue gases are only shown in the tabulation.

Of course, it is well-known that to burn fuels air is required. These two elements are needed to make combustion possible. It is necessary to measure the correct amount of air for the correct amount of fuel. Consequently, I suggest that Mr. Flagg include in his tabulation the correct figures for the amount of air required for each fuel, either in the form of weights or cubic feet per unit. These calculations have to be made anyway, and their publication will avoid any student having to make elaborate recalculations.

From the practical standpoint, the volumes of air required for combustion are very important, because the air has to be supplied by extraneous means, such as fans, stack effects, etc., which have to be correctly proportioned in any industrial application. This accessory equipment often determines even the economic value of some by-product fuel.

From the control standpoint, it is very important to consider the relationship between the "combustible" fuel and the "comburant" air, and maintain their ratios over the range of operation. The CO_2 content of the gases and the temperature in the furnaces are only effects or results of the combustion and as such depend on the correct supply of the two component elements, and we feel that Mr. Flagg's table should by all means include the data about the air, in order to increase the practical value of his tabulation.

H. V. Flagg: I haven't made this statement before but it has been in my mind. I expected to get as much from this paper as I gave or more in fact, because I have used this method many times and I wanted to learn what other people thought about it. In other words, if there are bugs in it I wanted to get them out, and hoped somebody would tell me about them.

As for the amount of air for the combustion of the unit amount of fuel, that, of course, has to be made in most calculations and could well be included in the data given in this paper.

F. E. Leahy: Did you set this value on coke gas for the whole plant from the value you placed on it at the boiler?

H. V. Flagg: Absolutely not!

F. E. Leahy: Or do you mean to use that for one application?

H. V. Flagg: For one application. I thought I made that reservation when I started. I said I was going to try to make enough reservations so I could get out from under anything that came up, but it is emphasized that these comparisons hold true only for the fuel analyses used and the flue gas analysis used, and, of course, for the application. If I didn't include the latter, it was an oversight as I meant to, but it holds as well there as for the other factors. There is no question about it. You couldn't use raw coal in an open hearth furnace, so that the value of coke oven gas compared to coal could not hold there. If it is a case of comparison with producer gas the gasification cost of coal rather than the cost of raw coal must be used and the basis of fuel analysis, flue gas analysis, and flue gas temperature must be those at open hearth conditions, and also the evaluation of the flame characteristic factor must be included. This latter is not a simple proposition and I hope somebody will find time and money enough to do sufficient research on the problem to work out a conclusive evaluation of the effect of flame characterstic, particularly in the open hearth operation. It would be very interesting to have these figures worked out.

George S. Hendrickson: I would like to ask a question of Mr. Shadgen who brought up the question of measuring the air. It seems to me that Mr. Flagg's flue gas analysis takes it into consideration.

J. F. Shadgen: It certainly does. All I sug-

gested is that Mr. Flagg put in his tabulation, the information about the air required for combustion so that it will be available without recalculation.

Concerning the evaluation of any fuel, it is of great importance to consider besides the problem of generation, the problem of absorption. This means the factors of concentration of heat, the pyrometric effect required, and the flame characteristic (oxidating, neutral, or reducing). These three factors have to be appraised before the final value of any fuel can be given for any purpose. These points have been brought out by other speakers and expressed in different words. This is one way in which engineers make their money.

Harry Dobrin: I would like to supplement Mr. Leahy's question about the value of coke oven gas. I wonder if Mr. Flagg wants to keep on good terms with the coke oven people. There is always a friendly conflict. The fuel engineer asks, "Is it 500 b.t.u. per cubic foot?" The coke oven man answers: "No, it is 510." Then the fuel engineer asks, "Is it gross?" The coke oven man says: "No, it is net." But you never hear of a 427 b.t.u. coke oven gas being sent to a steel plant, whether it be for boiler use or for any other purpose. From my personal experience, coke oven gas is always closer to 500 b.t.u. than it is to 400 b.t.u. I also wanted to know if Mr. Flagg was mindful of this condition when he mentioned a coke oven gas of only 427 b.t.u. value.

My further comment on this paper would be that so many phases of this problem have been brought out here by the other gentlemen in this discussion, and so many points have been developed, that there is material enough for a dozen papers on this subject. The question of control, the value of the flame temperature of the one fuel as against the theoretical flame temperature of the other fuel, the form of application, etc., have a greater effect upon thermal efficiencies than the mere question of the comparative b.t.u. value of the fuels. It is certainly not to be expected that one could derive as much value from slack coal as could be derived from a refined fuel in gaseous form.

I was hoping that Mr. Flagg was getting up a paper on the comparative values of the different fuels employed for metallurgical steel heating, and I am sorry to find that it was only treating on the application under the boilers. Had this paper been on the value for metallurgical heat application, there could have been a royal battle here right now.

Speaking generally about comparative values of fuels, they are meaningless from the standpoint of comparative results without regard to the particular form of application. I venture to say that there must be many here whose experience has been that taking the self-same fuel applied in one way and the identical fuel applied in the correct way, that they have experienced a reduction in the identical fuel by half or more, which shows that the value of correct application of fuel is by far the more important than the actual calorific values between one kind of fuel and another.

M. J. Conway: Thank you for your point that another paper is needed on this question. We will be very pleased to invite you to start off that series.

H. V. Flagg: I want to bring out one point again: I didn't want to set up comparative values of fuels. I wanted to point to a method of making fuel comparisons, and so I might better have left dollars and cents out of it entirely.

If we can start to think about pounds of coal in terms of available b.t.u. instead of gross b.t.u. or net b.t.u.—if we can learn to think about coke oven gas as having 427 b.t.u. or whatever may be available, fuels will come nearer being truly comparable.

Of course, that brings up another point, which is that every application is different and every condition is different, which changes all the conditions of the comparison and necessitates a new set of calculations for each application, with correspondingly different equivalent values.

I still maintain that under the conditions holding in the example discussed, that coke oven gas only has 427 b.t.u. per cubic foot available for useful work out of the 554 b.t.u. of potential heat in the gas.

M. J. Conway: Does that answer your question, Mr. Dobrin? If there are no other questions on this paper, I will turn the meeting over to Mr. Shoemaker who will take the chair for the next paper. Thank you, Mr. Flagg.

Modern Reversing Mill Drives

By R. H. WRIGHT*

One of the first main roll electric drives to be installed in an American steel plant was a reversing equipment. That the growth in the use of reversing drives has kept pace with the general trend of rolling mill electrification is indicated by the number of reversing equipments which have been built in this country. Up to the present time American manufacturers have supplied a total of 98 reversing equipments for installation in America, Canada, France, Spain, Japan and India. The combined continuous rating of these equipments is nearly 400,000 H.P. or practically 20% of the total horsepower of main roll drives built in this country, and their combined cost is probably more than 25% of the total value of all the main roll drives built by American manufacturers. These figures include several equipments for driving adjustable speed three high structural and rail mills which are reversed only infrequently, but which are identical in construction, appearance, control and method of operation with equipments used in reversing service.

The first reversing equipment embodied prac-

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tically all the fundamental principles employed in modern reversing mill drives, but since the initial installation there has been a steady development, resulting in refinements of construction and improvements in operating characteristics. The trend of development in rolling mill practice has been toward heavier ingots and higher outputs, resulting in heavier mills and driving units of larger capacity. It will be the purpose of this paper to review modern practices in applying electric drive to reversing mills and describe the general construction of the modern reversing equipment.

The greater part of the reversing equipments built in the United States have been applied to blooming and slabbing mills, the remainder being used to drive structural roughing mills, reversing beam mills, three high structural finishing mills, reversing plate and strip mills, rail mills, bar and billet mills and non-ferrous mills.

Reversing blooming mill drives built in the past few years have fallen into the following general classes:

Continuous Rating H.P.	Speed Range	Torque—Lbs. Ft. Circuit Breaker Setting	Maximum Operating
3750	0/50/120	1,000,000	850,000
5000	0/50/120	1,500,000	1,200,000
6500	0/60/120	1,500,000	1,200,000
7000	0/50/120	2,000,000	1,650,000
8000	0/40/80	2,500,000	2,000,000

The 3750 H.P. equipments have been applied to light 35″ and 36″ general purpose mills rolling 18″ to 22″ ingots to blooms ranging from 4″x4″ to 8″x8″ and larger and light slabs and beam blanks. Production of 4″x4″ blooms and small slabs is usually around 25,000 gross tons of finished steel and of mixed sections averaging larger than 4″x4″, approximately 30,000 gross tons, finished weight. With 25″ to 30″ diameter rolls in the mill a 3750 H.P. reversing equipment has sufficient torque to permit drafts of 2″ to 2½″ on 18″ to 20″ wide ingots.

There is now a tendency to build 36″ mills heavier, using them for medium work formerly done in 40″ mills and driving them with motors of more than 1,000,000 pounds feet torque capacity. A 5000 H.P. motor with a maximum torque of 1,500,000 pounds feet and a speed range of 50 to 120 R.P.M. will roll a wide range of product with a mill of this type. Where the output consists almost entirely of light and medium sections and where the tonnage available justifies the cost of a larger equipment, a 6500 H.P. motor with a full field speed of 60 R.P.M. can be used. A higher full field speed makes the motor livelier and make possible a greater production of smaller sections which are difficult to roll at high tonnage rates.

A reversing motor designed for a high full field speed can exert the same maximum torque as a machine built on the same frame but with a lower full field speed but the former machine requires a larger motor generator. For example, a motor frame normally built with an armature having a continuous rating of 3750 H.P. at 50 R.P.M. and a maximum torque of 1,000,000 pounds feet can be built with an armature having a full field speed of 70 R.P.M. This motor would have a continuous rating of 5250 H.P. and could exert a maximum torque of 1,000,000 pounds feet. In the first case the generator capacity would be 3000 KW. and in the second case the required generator capacity would be 4200 KW. The capacity of the driving motor of the motor generator would also be increased. The reversing motor itself could be more expensive because the commutator and other current carrying parts must be heavier.

It is interesting to note that one of the first reversing blooming mill equipments ever built has a full field speed of 70 R.P.M. This equipment has rolled 35,100 net tons of finished blooms, largely 5″x5″ or equivalent sections, from 20″x20″ ingots, in one month. Production in this mill will be increased to 40,000 tons per month in the near future.

7000 H.P., 0/50/120 R.P.M. drives are applied to heavy 40″ and 44″ mills designed to roll from 60,000 to 100,000 gross tons of heavy blooms and slabs from ingots 25″x40″ 25,000#, 25″x30″, 15,000# and smaller. A 7000 H.P. equipment will permit drafts of 3″ on 25″ wide ingots in a mill with 35″ diameter rolls. One 8000 H.P., 0/40/80 R.P.M. motor drives a 54″ mill used in roughing out heavy beam blanks from ingots up to 30,000 lbs.

The above examples are representative of modern blooming mill practice. In each case the motor has power to take as much or more draft as the largest ingot which can be handled satisfactorily by the mill will stand without damage to the steel and continuous capacity to drive the mill when rolling at the highest output possible with present practice.

The torque required to make a pass is determined by the reduction in section of the metal, the diameter of the mill rolls and the condition of the steel. The torque may be calculated from the expression.

$$T = A \times C \times 275 \times \text{roll diameter } X\ (1 - \%\ \text{reduction})$$

Where

T = Motor torque in pounds feet.

A = Reduction of area in square inches.

C = A constant which depends upon the temperature and density of the metal. A typical curve giving the value of C plotted against percent of original area is shown in Figure 1.

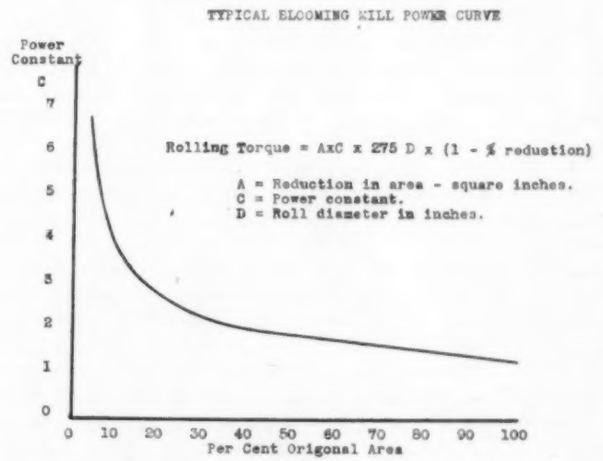

FIG. 1.

It will thus be seen that the maximum torque capacity required for a blooming mill, where the size of ingots and the maximum drafts have been decided on, is determined entirely by the diameter

of the mill rolls. For example, a pass which can be made in a mill having 35" diameter rolls with a motor torque of 1,600,000 pounds feet will require 2,000,000 pounds feet motor torque when made in a mill having 44" rolls. The mill with the larger rolls can, of course, make each pass in less time and therefore has a higher potential tonnage capacity, but it cannot be used for heavier drafts unless driven by a motor with torque capacity more than 44/35 greater than the torque capacity of the motor for the smaller mill.

A recent oscillograph test of a 7000 H.P. equipment driving a 44" blooming mill with 35" diameter rolls showed that, when rolling a 27"x32", 18,000# ingot with 3" drafts in the first 10 passes, the maximum torque exerted by the motor was 1,675,000 pounds feet. The ingot was of low carbon steel and the temperature leaving the pits was above the average. A higher carbon content or lower temperature would have made it impossible to roll the ingot without tripping the circuit breaker. Usually only low carbon steel can be rolled with such heavy drafts, as higher carbon rail and axle steel has been found to crack under such treatment. Normal practice on this and other similar mills is to limit the drafts to 2" until the ingot has been considerably reduced. A 7000 H.P. equipment which can take 3" draft under ideal conditions has ample reserve capacity to take care of normal drafts under average conditions.

Three-high rail and structural mills for rolling standard rails and shapes usually operate in conjunction with a 32" to 36" reversing roughing mill. The actual work done on the steel in the roughing mill, as expressed in kilowatt hours or horsepower hours, is comparatively small but the torque requirements are such that the motor should have a maximum torque of at least 1,000,000 pounds feet. More recent 36" mill installations have motors with maximum torque ranging between 1,000,000 and 1,500,000 pounds feet. The wide range of sections rolled in the roughing mill and the comparative shortness of the passes makes it desirable to use a low full field speed and, since 50 R.P.M. full field speed is high enough to enable the rougher to roll as much steel as can be handled by the finishing train, this speed has become practically standard. The use of low full field speed equipment also keeps the cost of the installation more nearly in proportion to the work done in the roughing mill.

It is well recognized that greater output is obtained from a three-high structural or rail finishing train when driven by an adjustable speed direct current motor with reversing mill type control. The average speed of the finishing train is higher than that of the rougher and the steel can be entered at a higher speed so a higher full field speed is used. A full field speed of 75 R.P.M. is practically standard for 28" mills and the continuous capacity of recent successful installations ranges from 5000 to 6000 H.P.

Universal plate mills, except those with large diameter rolls, have been found to require motors with high full field speed. The average 42" to 48" universal plate mill with rolls 32" in diameter has been found to operate successfully with a full field speed of 75 R.P.M. and a maximum speed of 120 to 130 R.P.M. The average rolling schedules for a 48" universal mill make it necessary to provide for maximum torques up to 1,000,000 pounds feet.

The drive for a reversing roughing stand of a tandem sheared plate mill is an interesting application. The roughing passes are of extremely short duration. An oscillograph test of an 84" mill having 32" diameter rolls showed that, in rolling a 3"x15"x36" slab to ¾"x37.5" in 7 passes, some passes were as short as ½ second and no pass exceeded 1 second. Due to the time required to set the screwdown and turn the slab the total time for 7 passes was 26 seconds. The metal was actually in the rolls only a very small part of the total time. In a speed trial, made when an order was being rolled which did not necessitate turning the slab, 7 passes could be made in 13 seconds. This reduction in time was not obtained by the use of higher rolling speeds, but by reducing the interval between passes. This mill has rolled for considerable periods with an average time of 4¼ seconds per pass, including the interval between passes and the time between slabs.

During the short roughing passes the greatest production can be obtained by keeping the slab as close to the mill as possible at all times and entering it in the rolls for the next pass in the shortest possible time. The slab thus enters the rolls at a low speed and the pass is completed before the motor can accelerate to a high speed. The motor can therefore be designed with a low full field speed and the generator capacity kept to a minimum. The work done on the steel in the roughing mill is comparatively small and the investment in driving equipment should likewise be kept low. The torque requirements vary with the design of the mill and the rolling schedules.

The torque can be calculated in the same manner as for a blooming mill, using suitable curves giving the variation of the constant C.

Where the finishing stand of a tandem plate mill is two high reversing, the motor characteristics are more like those of a universal mill drive.

For reversing bar and billet mills taking steel directly from the blooming mill it is common practice to apply a reversing motor with a moderately high full field speed. Two such equipments driving 30" bar mills have a full field speed of 65 R.P.M., a maximum speed of 130 R.P.M., a maximum torque of 700,000 pounds feet and a continuous rating of 3000 H.P.

In the preceding discussion considerable emphasis has been placed on the full field speed of the reversing motor. The torque requirement of a reversing mill is practically a fixed quantity and can be determined with sufficient accuracy, without difficulty, by calculation. However, the reversing equipment can be designed for any one of several full field speeds, so the engineer is called upon to select the correct speed. Once the equipment has been designed and built for a certain full field speed, the cost of making a change would be practically prohibitive. Fortunately, existing installations cover such a wide range of rolling conditions that past experience furnishes a valuable guide in applying motors to new mills.

Early reversing mill drives were installed at a time when mills were generally lighter, the ingots smaller and production lower than at present. The constant demand for more power to take care of greater tonnages and to handle heavier ingots made it necessary to increase the torque capacity and the

continuous capacity of the driving equipment. At the same time it has been necessary to make improvements in construction to keep pace with the general advance in machinery design. Reversing equipments have been improved by simplification and refinement of design, substitution of structural steel parts for cast parts and improvement of the control. One of the chief design improvements has been the use of single unit armature construction for large capacity machines to replace the double unit armature construction previously employed.

Increasing the continuous rating and peak capacity of a direct current machine tends to make commutation more difficult. The fields of modern reversing motors and generators are therefore very carefully designed to give good commutation. The interpoles are tapered to assist in keeping the magnetic flux in the commutating zone portional to the load at all times and the compensating pole face windings are carefully designed to reduce the effect of armature reaction to the minimum.

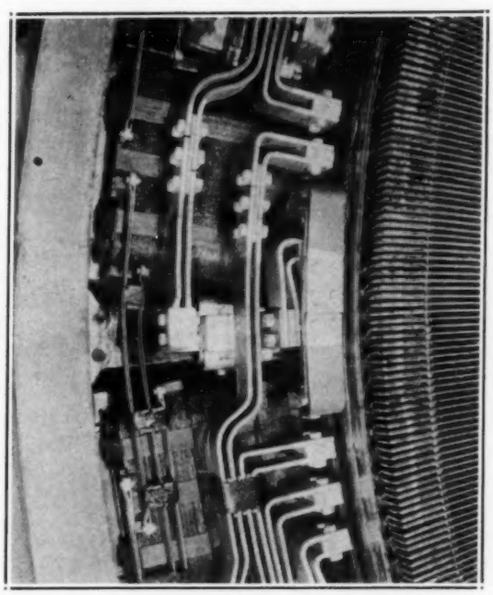

FIG. 2—Reversing Motor Field Windings showing connections at Frame Split.

Figure 2 is a view of a section of the field of a modern reversing mill motor showing the pole face, interpole and main field windings. It will be noted that the sides of the interpole coils are made parallel to the sides of the interpole, thus giving uniform and ample clearance between the interpole coil and adjacent coils and pole tips. The method of connecting the main field interpole and compensating windings at the frame split is shown in this view. The shunt field coil connections are brought to the commutator end of the machine where they are visible at all times.

In the past field frames have been steel castings but recent advances in the art of fabricating machines from rolled steel by electric arc welding have made it possible to take advantage of the more homoeogenous structure and better magnetic qualities of rolled steel by designing the motor with a rolled steel frame. Figure 3 is a shop view of a motor recently constructed with a rolled steel frame.

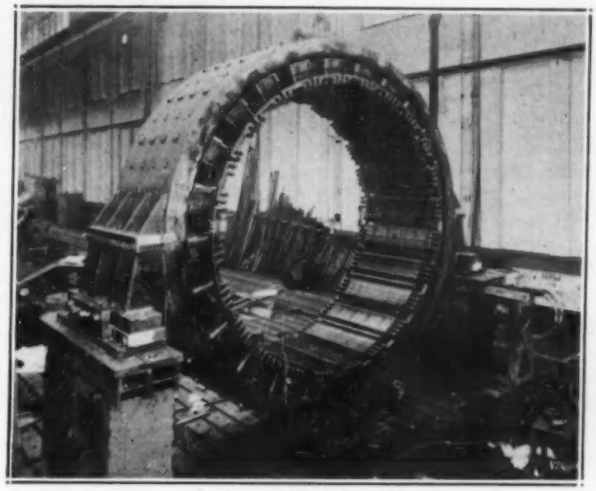

FIG. 3.

Figure 4 is a cross section drawing which indicates the general construction features of a reversing motor. The armature spider is a heavy steel casting with H section arms and having dove tail slots milled on the outer circumference on which the armature punchings are assembled. The laminations are clamped in place between two heavy cast steel end rings which also serve to support the armature coil ends. The supporting end rings are not solid but are cast with openings which allow the air to flow through the armature end windings.

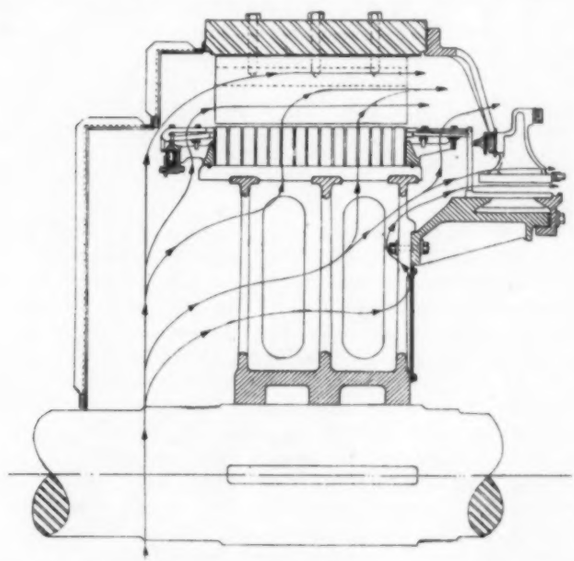

FIG. 4—Section through modern reversing motor showing path of ventilating air.

The armature coils extend out from the iron core as much as a foot or more on either side. Because of the sudden changes in the speed of rotation of the armature the coil extensions must be held in place very firmly to prevent movement of the coil ends and breakage of the insulation, at the point

where the coil comes out of the core. Field tests have shown that the rate of change of speed during a reversal of the armature may for short periods exceed 100 R.P.M. per second. With an armature 12 feet in diameter changing speed at the rate of 100 R.P.M. per second, a weight of 1 pound at the surface of the armature exerts a tangential pull of 2 pounds. With heavy coils it is evident that considerable bending moment is exerted at the point where the coil leaves the core. Bracing is obtained by means of teeth on the steel end rings. These teeth are formed from a strap of cold rolled steel and arc welded to the end rings.

The armature coils themselves must be made with the greatest care. A typical insulation specification is given below.

(a) Insulate conductors all around with mica tape half-lapped. Two layers on the middle conductor and one on each of outside conductors.
(b) Bind coil all around with cotton tape not lapped but drawn tightly.
(c) Bakelize straight parts and press coils to shape in steam press.
(d) Dip ends in varnish and bake.
(e) Apply mica wrapper to straight part and tape end portions with the layer of mica tape.
(f) The complete coil taped with cotton tape not lapped on straight part and half-lapped on ends.
(g) Singe tape and treat coil ends five times in baking insulating varnish. Apply two treatments of baking insulating varnish to straight portions.
(h) After armature is wound complete rotor treated twice with varnish and baked after each treatment.
(i) Test at 3500 volts.

The more recent motors do not have a commutator spider but have a commutator which is built up on a large cast iron ring. This ring is machined to fit into depressions cut in the arms of the armature spider and is bolted to the spider. This construction is shown in Figure 4.

The change from the double unit armature to a single unit armature for large capacity machines has been mentioned as one of the improvements in reversing motor design. The single unit armature gives a better motor because it is simpler on account of having but one commutator, there is less inertia, since the amount of inactive material is reduced and in general the single unit armature is more efficient. The single unit motor is built on shorter centers and is therefore more rugged mechanically.

Reversing motors have always been built with heavy shafts, large bearings and with heavy bedplates. Earlier installations did not have an oiling system and the oil rings were depended on to carry oil from the well in the base of the bearing to the bearings. Since the average speed of the motor was low it was felt that the rings might not carry sufficient oil to keep the bearing cool so water cooling coils were used in the lower half of the bearings. Experience has shown that there are practically no instances where the water was actually required to cool the bearings, and there have been cases of trouble due to freezing of the water and from leakage due to corrosion of the cooling coils. It has now become the universal practice to install a circulating oiling system and the more recent reversing motor designs include bearings which will operate without water cooling.

The pedestal next to the mill is always made heavy and of cast steel. This pedestal carries a thrust bearing which is designed to take emergency thrust from the mill. Except in special cases this bearing is not good for any continuous thrust. In one case where a motor was installed to drive an old mill which had worn pinions and couplings a specially designed thrust bearing was used which could take a certain amount of thrust from the mill. The rear pedestal is secured to the foundation independently of the bedplate by foundation bolts which not only extend through the feet of the pedestal but also through the pedestal cap. Instances have been recorded where a motor received thrust from a broken mill spindle sufficient to move the mill out of vertical alignment without movement or damage to the motor.

With this rugged bearing construction the principal function of the bedplate is merely to assist in lining up the parts of the motor during installation. Except in special cases the top of the bedplate is made flush with the floor and the bedplate serves to secure alignment before grouting. Modern practice is to fabricate the bedplates by arc welding from rolled steel beams. Figure 5 is a shop view of a motor with a structural bedplate.

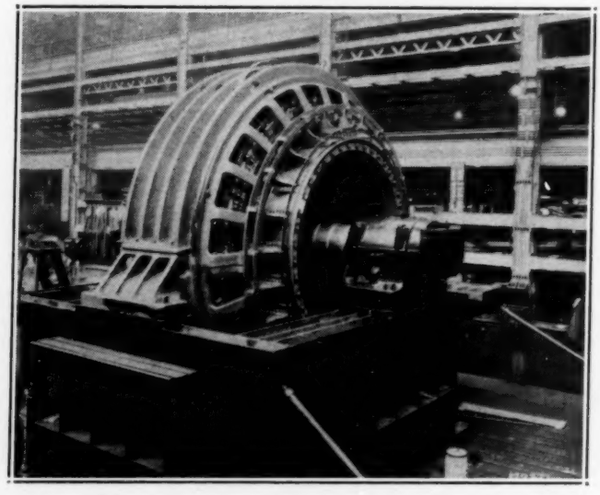

FIG. 5—Shop view of reversing motor, showing structural bed-plate.

Two reversing motors have been built recently with structural steel sole plates. Figure 6 shows one of these machines in operation.

Sometimes where space is limited or a low cost drive is desired it would be desirable to use a high speed geared reversing motor. However, there are factors which fix the limit of size for which a high speed reversing equipment can be built. The principal limiting feature is the greater flywheel effect of the high speed motor. For example, the largest D.C. adjustable speed motor with reversing motor type control is a 3000 H.P., 325-485 R.P.M. machine driving a 24" structural mill through reduction gear-

ing at a speed of 70 to 105 R.P.M. This motor has a WR^2 of 71,000 lbs. ft.^{2} and a kinetic energy of 5170 H.P. seconds, at 485 R.P.M. A direct connected motor to do the same work would have a WR^2 of 515,000 lbs. ft.^{2} and a kinetic energy at 105 R.P.M. of 1750 H.P. seconds. The control of the direct-connected motor should be adjusted so that at reversal the motor would drop from 105 R.P.M. to zero in two seconds. With the control set to maintain the same reverse current the high speed motor would require 5.9 seconds to come to rest from 485 R.P.M. Obviously a motor which required 6 seconds to come to rest from maximum speed or approximately 12 seconds for a complete reversal would be of little value on a reversing mill drive. By building the high speed motor with a double unit armature the inertia could be somewhat reduced but unless a design were extremely special the time of reversal could not be made to even remotely approach that of the direct-connected motor. The multiple armature machine would become expensive and more complicated and its use would defeat the purpose for which this design was intended.

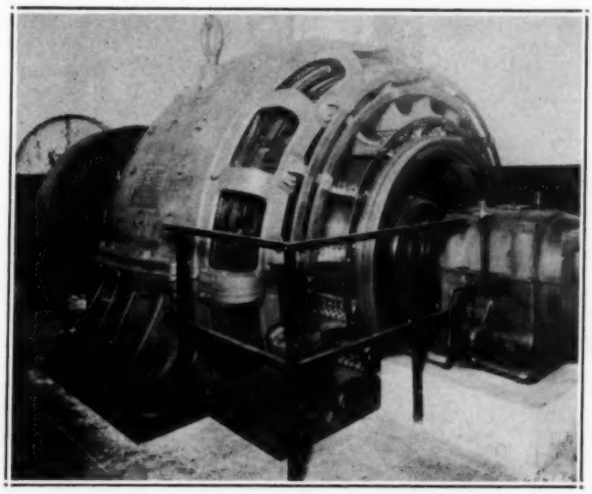

FIG. 6—Installed view of reversing motor having sole plate mounting.

Generators for reversing mill service must be designed for the same peak loads as the reversing motor so that, aside from their being designed for higher and more nearly constant speeds, their electrical construction is similar to that of the reversing motor. The tendency has been to design the units for relatively large capacity at a speed of 360 or 375 R.P.M. as compared with the European practice of using a number of high speed generators of low capacity. At present the tendency is toward the use of higher speeds and sometimes employing two high speed generators operating in parallel to do the work of a single generator of lower speed. By taking advantage of the accumulated experience and research in design and by careful attention to details it is possible to obtain as satisfactory performance at higher speeds as at low speed.

Two motor-generators placed in operation within the last two years run at 750 R.P.M. synchronous speed. Each set has two 1500 KW. generators operating in parallel, thus giving the same capacity as a 375 R.P.M. single generator set. Over a year of service under severe operating conditions has shown this design to be entirely satisfactory. Another recent installation has two 3500 KW., 700-volt generators operating at 375 R.P.M. synchronous speed. These generators were tested at 15,000-ampere peaks, or three times normal full load, indicating that they are conservatively rated at 375 R.P.M.

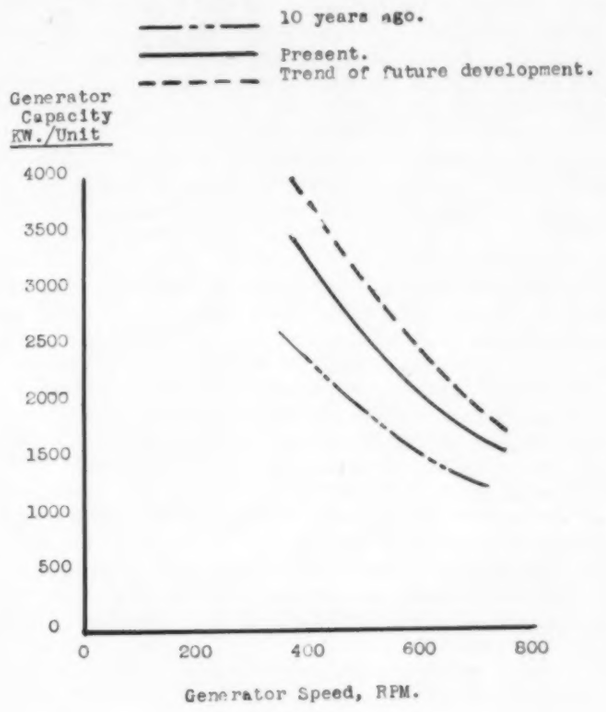

FIG. 7.

In Figure 7 the middle curve shows the relation between kilowatt capacity per generator at 50°C. rise and generator speed for a number of recent installations. Comparison with the bottom curve, which shows the speeds in use about ten years ago, indicates the progress which has been made in that time. The top curve has been drawn to indicate the possible trend of future development.

The design of an induction or synchronous motor to drive the set presents no special problems for any speed satisfactory for the generators. The use of plate steel flywheels has now become general and because plate flywheels can be designed for rim speeds of 22,000 feet per minute as compared to 17,000 feet per minute for cast steel wheels, flywheel weights have been reduced. Flywheel bearings are being designed so that water cooling is not required. Bedplates are usually fabricated from rolled steel and the set installed so that the top of the bedplate is flush or slightly below the level of the motor room floor.

In the past practically all equipments have had motor-generators with flywheels to equalize the peak loads. Blooming mills and roughing mills impose peaks of from 10,000 to 20,000 horsepower and the metal is in the rolls only about one-third of the total time. Very few existing power systems could successfully handle a load of this type without a means of equalizing the peaks. Finishing mills such

as reversing bar and billet mills or three high structural and rail mills are not subjected to such violent peaks and the equipment operates at a higher load factor. In many cases the power system has sufficient capacity to handle such a load without equalization of the peaks. In such cases a synchronous motor-generator has been found satisfactory. The 3000 KW., 750 R.P.M. motor-generator which operates in connection with the reversing bar mill drive, shown in Figure 6, has a synchronous driving motor.

A synchronous set can either be operated with full excitation on the motor at all times or the motor excitation can be reduced to a value which will permit it to handle normal loads without pulling out of step and using a quick acting relay to apply the additional field required for unusual peaks. The latter arrangement reduces the heating of the synchronous motor and cuts down the excitation losses of the equipment.

The primary and secondary control for induction motors driving flywheel motor-generators and the primary and field control of the motors on synchronous motor-generators have become so standardized that this part of the reversing equipment control need not be discussed here. The design of the field control of the reversing motor and the generators has received a great deal of attention as the operating characteristics of the reversing motor are determined almost entirely by the manner in which the control functions.

The modern field control has as its nerve center a contactor and relay panel which, although little larger than a heavy crane control panel, provides six points of speed control in either direction of rotation, overload, overspeed, overvoltage and no voltage protection, means of regulating the rate of acceleration and retardation and the maximum torque exerted by the motor and control for maintaining a predetermined voltage on the generators over a wide range of conditions. Two overload devices are provided. The main carbon circuit breaker between the generators and the motor has an overload trip which is set to operate only in emergencies. When this circuit breaker opens on overload it can be reclosed only by the motor room attendant, thus insuring that the equipment will not be placed in operation again unless the attendant is satisfied that no serious trouble has occurred. Normal overloads caused by excessive drafts or cold steel cause a quick acting relay to operate which opens a contactor in the generator excitation circuit and operates a green light in the pulpit. This field circuit breaker resets instantly when the master switch is brought to the "off" position. By this means the operator is warned that he is exceeding the capacity of the equipment without holding up production.

Everyone has become accustomed to the use of automatic machines for a great many purposes. Likewise, engineers are accustomed to applying motors with special characteristics and special control to automatic devices. Reversing mills have not been generally designed for automatic operation, but this is not because of any limitations in the driving equipment. Since the control operates entirely on the field circuits and the field circuits can be designed to give almost any desired characteristics, the reversing motor can easily be adapted to the work in connection with an automatic control scheme requiring special motor characteristics.

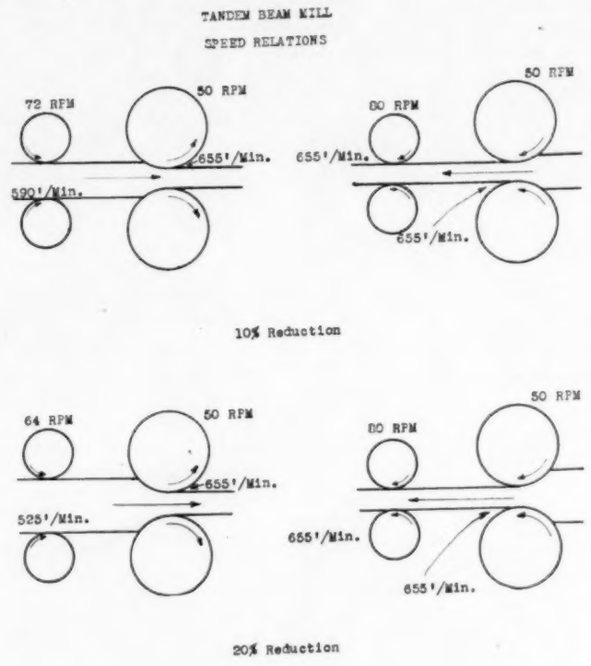

FIG. 8.

A slabbing mill or a beam mill arranged for two motor drive are examples of a special application which will serve to illustrate how large reversing motors can be made to operate in conjunction with automatic control. Figure 8 shows the arrangement of the main horizontal and edging rolls in a beam mill. A third set of rolls not shown in the sketch have their centers in the same vertical plane as the main horizontal rolls and make the same percentage reductions as are made in the main horizontal rolls. All three sets of rolls are set automatically for each pass by means of automatic screwdown control. In this figure the effect on the speed of the edging roll of changes in draft and direction of travel of the steel is indicated. It has been assumed that the metal is not actually elongated in the edging rolls, but is merely held to shape. It will be noted from the figure that in one direction of travel the speed relations are determined only by the relative roll diameters and are not affected by the draft on the steel. In the other direction the speed of the edging roll must be corrected for the draft in the main rolls.

Figure 9 shows diagrammatically the special conditions which must be met during acceleration and retardation of a beam mill. The base line represents time to accelerate or retard the motors. Under normal operating conditions the main roll motor will accelerate to its maximum speed of 80 R.P.M. in a definite time and the line OA has been drawn to represent the acceleration curve of this motor. The edging roll motor under one condition of operation will be required to accelerate from zero speed to 91 R.P.M. in the same time that the main motor accelerates to 80 R.P.M. Line OB represents this speed time curve of the edging roll motor. Under another condition the edging roll motor is required to accelerate from

zero to 163 R.P.M. in exactly the same time, as represented by line OC. To avoid heavy circulating currents between the two motors during regeneration it is also essential that the motors come down in speed together regardless of the speed of the edging roll motor at the instant reversal is started. That equipment which meets all the above conditions is in successful operation indicates the possibilities for automatic control of large reversing motors.

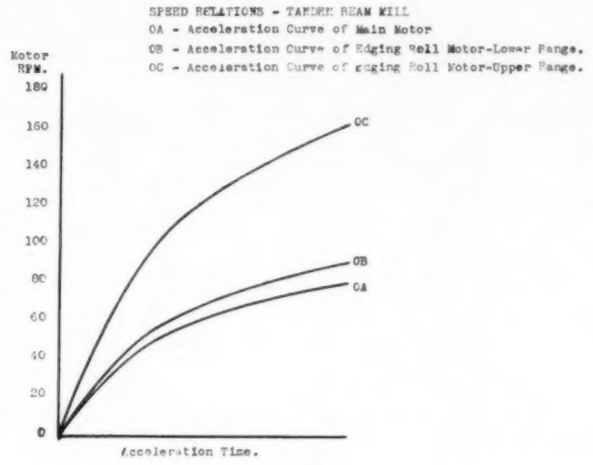

FIG. 9.

In one plant beams are rolled in two mills as described above, one mill acting as a rougher and the other as a finisher. Each beam mill has two main motors having a combined capacity of 9,000 H.P. The steel may be passed from 7 to 15 times through either mill in being reduced to the finished section and at each pass of the beam seven adjustments of the mill must be made. Four of these adjustments must be very accurate and all adjustments must be made in the three or four second interval between passes. Each mill has only one operator and he does little more than watch the operation of the mill and decide when the metal shall be allowed to enter the rolls.

The schedule of reductions required to produce a given beam is calculated in the plant engineering department and forwarded to the mill crew with the order for the desired quantity of that beam. The schedule of reductions is set up on electrical plug boards in a few minutes' time and rolling immediately started. After each pass of the metal through the mill the operator merely moves a lever ahead one notch and the rolls are set automatically for the next pass and signal lamps are lighted to indicate that the steel can be started through the mill again. By this system of automatic control the two mill operators are able to do the work of six routine operators and at the same time turn out a more uniform and accurately rolled product.

A mill of this type has more of the characteristics of an automatic machine tool than of the conventional rolling mill. However, it seems logical that a mill should come to be looked upon as a machine for producing, at a definite rate, certain finished products of uniform size and quality without detailed supervision of every step, rather than as a means of performing a series of individual operations, the success of which are dependent on the skill of a number of men of varying capabilities. The modern reversing equipment has been developed to the point where it is suitable for use with automatic mills and further development can be expected along this line.

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*Flow Measurement in Connection with Coke Oven Gas**

By J. M. SPITZGLASS†

In the volumetric measurement of gases there should be a clear understanding of the so-called "base" or the standard unit by which the volume is measured. For our purpose the consideration of two standard units is sufficient. One unit is the amount of dry gas that will fill a space of one cubic foot at an absolute pressure of 30 in. of mercury and a temperature of 60 degrees F. This unit will be designated as the dry standard cubic foot or the 30 and 60 dry base. The second unit is the amount of gas that will fill the same space of one cubic foot at the same atmospheric pressure of 30 in. of mercury and a temperature of 60 degrees F., but which at the same time is saturated with water vapor. This unit will be designated as the saturated standard cubic foot or the 30 and 60 saturated base. Other bases may be specified in a similar manner.

In any case of base determination, we are concerned only with the gaseous mass contained in the given standard cubic foot. In the gases ordinarily produced or distributed, the presence of water vapor is of consideration only in that it takes up space and thereby reduces the amount of gaseous matter that would have otherwise filled that space. At 60 degrees temperature, the amount of water vapor that would fill a space of one cubic foot has a weight of .00828 pounds. This weight of water vapor completely fills the space and exerts a pressure of .522 in. of mercury.

Filling the space of an enclosed vessel with water vapor to the saturation point at the given temperature precludes the existence of more vapor in that

*Presented before the Association of Iron & Steel Electrical Engineers, February 7, 1930, Youngstown, Ohio.

†Vice president of Republic Flowmeters Co., Chicago, Illinois.

vessel. The same vessel, however, may in addition be filled with other gases, which merely build up additional pressure in proportion to the amount of gas added. The total pressure in the vessel is then the sum of the two—the vapor pressure and the gas pressure. These are usually designated as the partial pressures of the respective fluids. At 30 and 60 saturated, for instance, the water vapor contributes a partial pressure of .522 in. of mercury, or 1.74 per cent of the total pressure, irrespective of the nature of the gas contained in the vessel. The partial pressure exerted by the gas is 29.478 in., or 98.26 per cent of the total, and therefore, the weight of gas present in the vessel is only 98.26 per cent of the amount that would be contained if the vessel were filled with dry gas.

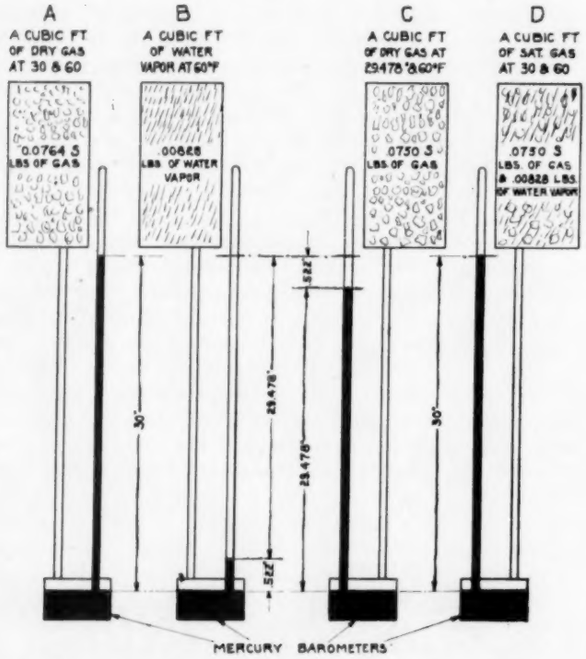

A
A CUBIC FT OF DRY GAS AT 30 & 60
.0764 S LBS OF GAS
B
A CUBIC FT OF WATER VAPOR AT 60°F
.00828 LBS OF WATER VAPOR
C
A CUBIC FT OF DRY GAS AT 29.478 & 60°F
.0750 S LBS OF GAS
D
A CUBIC FT OF SAT. GAS AT 30 & 60
.0750 S LBS. OF GAS & .00828 LBS. OF WATER VAPOR
30"
29.478"
29.478"
.522"
.522"
30"
MERCURY BAROMETERS

Fig 1. DIAGRAMATIC OUTLINE OF TOTAL AND PARTIAL PRESSURES IN A 30 AND 60 STANDARD CUBIC FOOT.

Fig. 1 shows a diagrammatic demonstration of the total and partial pressures in the standard cubic foot at 30 and 60. In that figure diagram A illustrates the dry standard cubic foot consisting of .0764 pounds of air, or .0764 S pounds of gas of specific gravity "S" as referred to air. This weight of gas in one cubic foot balances a barometric pressure of 30 in. of mercury at 60 degrees F. temperature.

Diagram B of Fig. 1, shows the volume of one cubic foot of water vapor at 60 degrees F. The weight of that vapor is .00828 pounds, and that amount of vapor balances a barometric pressure of .522 in. of mercury.

Diagram C, shows a cubic foot of dry gas at a pressure of 29.478 in. of mercury and 60 degrees F.; that is, one whose pressure is short of 30 in. by the amount equal to the vapor pressure at 60 degrees. The gas weight is .0750 S pounds, or 98.26 per cent of the weight that maintains 30 in. of barometric pressure as in Diagram A.

Diagram D, shows the standard cubic foot of gas at 30 and 60 and saturated with water vapor. This diagram shows the physical equivalent of Diagram B and Diagram C, placed in the volume of one cubic foot. The gas and the vapor each fills the entire space and each contributes its own partial pressure. The weight of the mixture is the sum of the weights of the gas and the water vapor. The combined weight of the two balances a barometric pressure of 30 in. of mercury. It is thus demonstrated that the difference between the dry standard and the saturated standard at 30 and 60 is that the latter cubic foot contains 1.74 per cent less gas than the former. In other words, the cubic foot of the 30 and 60 saturated base is 1.74 per cent lighter than the cubic foot of the 30 and 60 dry base.

Even more important than the understanding of the base is the clear conception of the terms density and specific gravity as referred to a gaseous substance. The density of a fluid is the quantity of mass contained in a unit of volume, or as it is usually stated, the weight in pounds of the total substance contained in a volume of one cubic foot. In a mixture of dry gas and water vapor, the dry gas part is assumed to vary in density according to the simple gas equation. The water vapor on the other hand is subject to the more complicated steam formulas. The actual density of the fluid is the sum of the weight of the gas and the weight of the water vapor contained in a unit of volume.

Specific gravity has reference only to the dry gas part of the mixture. The specific gravity of a gas is the ratio of the weight in a unit volume of the gas to the weight of an equal volume of atmospheric air. It is usually assumed that both the gas and the air equally follow or equally deviate from the simple gas equation. Naturally the change in pressure or in temperature does not change the specific gravity of the gas. It is understood, of course, that a determination of specific gravity requires the comparative weight of the gas and of the air at the same pressure and at the same temperature and free from water vapor. In actual testing, a correction is made for the vapor present at the given temperature.

In all cases of flow measurement the actual density of the gas at flowing conditions becomes the important feature. The drop of pressure through the measuring device is proportional to the velocity squared times the density of the fluid, and while we are principally after the determination of the velocity, we cannot obtain it unless we assume a certain density. In other words, the mechanism of the meter, actuated by the pressure difference, draws the record of the rate of flow and integrates the total flow, subject to a certain definite density that was referred to in the specifications for the given meter. If the fluid is maintained at the same pressure, the same temperature, the same degree of saturation as in the original calculations, and the gas is at the same specific gravity, the meter as set by the manufacturer will correctly register the rate of flow in cubic feet of the specified standard or base. If, however, as is usually the case, conditions vary from those specified, the registration of the meter must be interpreted in accordance with the corresponding change in density.

In the interpretation of results obtained with a flow meter on coke oven gas, the effect of moisture

in the gas is the main stumbling block, particularly where the gas is only partially saturated. It is the object of this paper to bring about a clear understanding of the density factor at varying conditions of flow and to give a method that will simplify the process of flow measurement in connection with coke oven gas.

For the purpose of analysis it is convenient to consider the gaseous fluid as a mixture of dry gas and water vapor in varying proportions. The usual difficulties of correcting for moisture content arise from the fact that a given amount of water vapor, as determined by temperature and degree of saturation, does not hold the same proportion to the density of the gas when the pressure or the specific gravity of the gas is varied.

In the case of dry gas the three variables—pressure, temperature and specific gravity—have strictly definite relations, and their resultant correction factor is simply a product of the three individual correction factors. When a correction is obtained for pressure variation. that correction applies to any temperature and to any specific gravity, and the same is true for temperature and for specific gravity corrections. The correction factor for water vapor, on the other hand, varies in magnitude, primarily, with the temperature and the degree of saturation, and also to a certain extent with the pressure and the specific gravity of the flowing gas.

A great deal of work has been done in arriving at a convenient form of equation to be applied to coke oven gas as used in the steel mills. In September, 1923, a standard formula was derived for saturated gases, and tables and curves were prepared for the correction factors. These factors were correct only for complete saturation. However, this is seldom the case in coke oven gas which has been delivered through a pipe line of some length. The gas is usually cooled to some low temperature and then warmed before reaching the metering point, resulting in the gas being only partially saturated at the measuring point. The method of correction for all such cases was very complicated, as it involved the determination of the degree of saturation at the increased temperatures.

In the present method the terms of the general formula are separated into two distinct parts, one embodying the dry gas part of the mixture and the other embodying the correction for the moisture content in the mixture. This splitting up of the formula makes it possible to refer directly to two independent temperatures in any case. The dry gas part of the mixture is corrected according to the temperature of the gas at the point of measurement. The correction for moisture is referred directly to the dew point temperature or the minimum temperature to which the gas was subjected on its way to the measuring point.

In order to show the application of the method, two sets of curves are included in this paper. One set covers the dry gas part and corrects for variation in pressure, temperature and specific gravity. The other set corrects independently for the moisture content at flowing conditions. Sets of curves have been drawn for several arbitrary specific gravity standards. That is, in each case the definition includes also an arbitrary specific gravity standard, .40, .60 or 1.00. Thus we say the base is 30, 60 and .40, the gravity value having its significance only in the computations and in the makeup of the curves, which are thereby considerably simplified. The arbitrary specific gravity standard is automatically eliminated in the actual use of the curves.

The main advantage, which puts these curves in a class by themselves, is the possibility of shifting from one base to another, or from one set of average conditions to another by the addition of only one single reference line for each given case. Curve sheet Fig. 2 (211-.40) shows a set of dry gas curves to a base of 30 and 60 and .40 specific gravity. Corrections for deviations from the base are obtainable for a variation of pressure from 25 in. to 100 in. of mercury absolute pressure for a variation of temperature from 32 degrees F. to 200 degrees F., and for a variation of specific gravity from .30 to .70. Similar sets have been prepared for bases of 30 and 60 and .60 specific gravity, and 30 and 60 and 1.00 specific gravity, with corresponding variations on each side of the base.

Fig. 3, is a set of curves used to correct for the moisture content in the gas. This set also involves the three variables, the pressure, the temperature and the specific gravity. It covers a pressure range from 20 to 120 in. mercury absolute pressure, a dew point temperature range from 32 degrees F. to 140 degrees F. and a specific gravity range from .30 to 1.00. The temperature of the flowing gas at the measuring point is not to be considered when correcting for moisture, unless it is the same as the dew point or minimum temperature to which the gas has been subjected. These curves clearly demonstrate the effect of each variable on the correction factor for moisture in the gas.

Two examples, Case 1 and Case 2, have been carried through in dotted lines on both sets resulting in two reference lines that have been added in Fig. 4, which otherwise is a duplicate of Fig. 2. A reference line on the dry gas set establishes a given specified average condition and replaces the base line for that set of conditions. Through this addition, all future corrections are obtained for the respective variations from the specified average conditions.

The two examples selected happen to be the first two cases on which the curves were applied. The conditions specified differ only in average temperature and degree of saturation. They were selected for demonstration to show the importance of these factors even in cases where the other conditions are the same. Another item of importance was that the meters were computed originally for a 30 and 60 saturated base and afterwards were changed to a 30 and 60 dry base. This was taken care of by including the corresponding multiplier in the reference line without any change in the original constant of the meter in the method of computations.

The method of using the curves is best demonstrated by following through the computations required for the average conditions of the two cases as shown by the dotted lines on the curve sheets. The conditions specified were as follows:

Meter Specification for Measurement of Coke Oven Gas
Base 30 and 60 Saturated

	Case 1	Case 2
1. Pipe Line	Branch	Main
2. Internal Pipe Diameter, D	6.065"	12.000"
3. Average Gauge Pressure	17 oz	17 oz

4. Average Barometric Pressure	29.4"	29.4"
5. Average Absolute Pressure, P	31.56	31.56
6. Average Absolute Temperature, T	540	522
7. Average Dew Point (assumed), t	80	62
8. Average Specific Gravity, S	.3542	.3542

The meter capacity, or maximum hourly rate, was determined from the formula:

$$Q = A\,C\,d^2\,\sqrt{h\,max}\,N\,K\,Z$$

The meaning of the terms in this equation and their values for the two cases under consideration are tabulated below.

	Case 1	Case 2
Q = Maximum hourly rate = saturated std. cu. ft. at 30 and 60	55000	250000
A = Constant determined by unit system	2053	2053
C = Orifice coefficient	.6412	.7197
d = Orifice internal diameter	3.187"	8.822"
$\sqrt{h\,max}$ = Scale constant	3.96	2.013
N = Base factor	1.017	1.017
K = Dry gas correction	1.068	1.088
Z = Correction for moisture	.957	.976

It will be observed, with reference to the dotted lines, that Fig. 2, as it stands, offers a diagrammatic solution for the correction factor K, to a standard base of 30 and 60. This set of curves gives the solution of the equation

$$K = \sqrt{\frac{P}{P_0}\,\frac{T_0}{T}\,\frac{S_0}{S}}$$

In other words, the set of curves in Fig 2, with the base line as given, is applicable to correct for the deviation of the flow from standard conditions of 30 and 60 and .40 specific gravity. This application is demonstrated by the dotted lines which show the value of K, the dry gas correction factor, for the two cases under consideration. This value can be determined from the set of curves much simpler than it could be computed mathematically.

Fig. 3, offers the solution for Z, the correction factor for water vapor, and the dotted lines indicate the values obtained for the two given cases. Thus it is possible to use the two curves as they are for any condition deviating from the standard, if the original computations were based on flowing conditions identical with the conditions of the standard cubic foot.

In practice, however, it is more convenient to compute the meter constant for average conditions. Such a procedure requires a smaller amount of correction; in fact the reading of the meter, as based on average conditions, gives the actual quantity over a long run, and therefore, it is best to adhere to this method.

This shifting from the base to the average, as stated, is accomplished by placing a reference line for each case on the same set of dry gas correction curves. Furthermore, this reference line is not limited to corrections applicable to the dry gas part, but it is made to include also the vapor correction that is obtained from the second set of curves. In addition, the reference lines, as shown on Fig. 4, were made to include the desired shift from the saturated to the dry standard cubic foot. Thus we have three correction factors in each of the two cases, K, Z and N. For Case 1, the product of the three factors is equal to 1.0392. For Case 2, the product of the three factors is equal to 1.078. The corresponding reference lines for the respective conditions are so drawn that each point on the reference line is equal to the corresponding point on the base line, divided by the product of the three factors. The dotted lines on Fig. 4 are used as an illustration and also as a proof of the method. These dotted lines primarily indicate the procedure of obtaining the dry gas correction factor using the reference lines instead of the base line. The conditions to which these lines apply are those for which the respective cases were computed, and for which the reference lines were prepared. For Case 1, the dry gas correction is shown to be 1.028, and the correction for moisture from Fig. 3 is .957. The product of the two is .984 and not unity. The reason is that the reference lines, as stated, were made to include also a change from the saturated to the dry standard cubic foot, involving the base factor, N, equal to 1.017, and that unity divided by 1.017 is equal to .984. For Case 2, the dry gas correction is 1.0075, and the correction for moisture from Fig. 2 is .976. The product of the two is .984, the same as in Case 1 because the reference line in Case 2 also included the change from the saturated to the dry standard cubic foot. In other words, the change to the larger unit in these cases reduces the meter constant in the corresponding ratio of the two units which is 1.00 to .984. In ordinary cases this factor does not come in and the product of the two corrections is unity for the average conditions for which the reference line is drawn. In any case when conditions vary from the average, the correction factor on the dry gas curve for the new conditions, multiplied by the correction factor on the saturated curve, also for the new conditions, will give the correct factor for the corresponding flowing conditions of the gas.

Summary

The following is a summary of the salient points to be considered in the measurement of coke oven gas as discussed in this paper:

(1) The standard cubic foot of gas is an arbitrary quantity based on a given definite amount of dry gas contained in the specified standard. A shift from one standard to the other means a corresponding change in the yard stick with which the gas is measured. An increase of the amount of dry gas in the standard cubic foot results in a corresponding reduction of the number of cubic feet in the measured quantity.

(2) The density of the gas as referred to in all cases of flow measurement is the weight in pounds of the total substance, contained in a volume of one cubic foot at the flowing conditions at which the gas is being measured.

(3) The specific gravity of the gas as compared to air is based upon the ratio of the weight in a unit volume of the dry gas to the corresponding weight of dry atmospheric air when the two are determined at the same pressure and the same temperature and corrected for the presence of water vapor.

(4) The determination of the gas quantity is arrived at by two distinct factors: one consists of a partial solution for the dry gas independent of the degree of its saturation with water vapor, while the other consists of the solution for the effect of water vapor in the gas. In cases where the gas contains no water vapor, the solution of the dry gas part gives

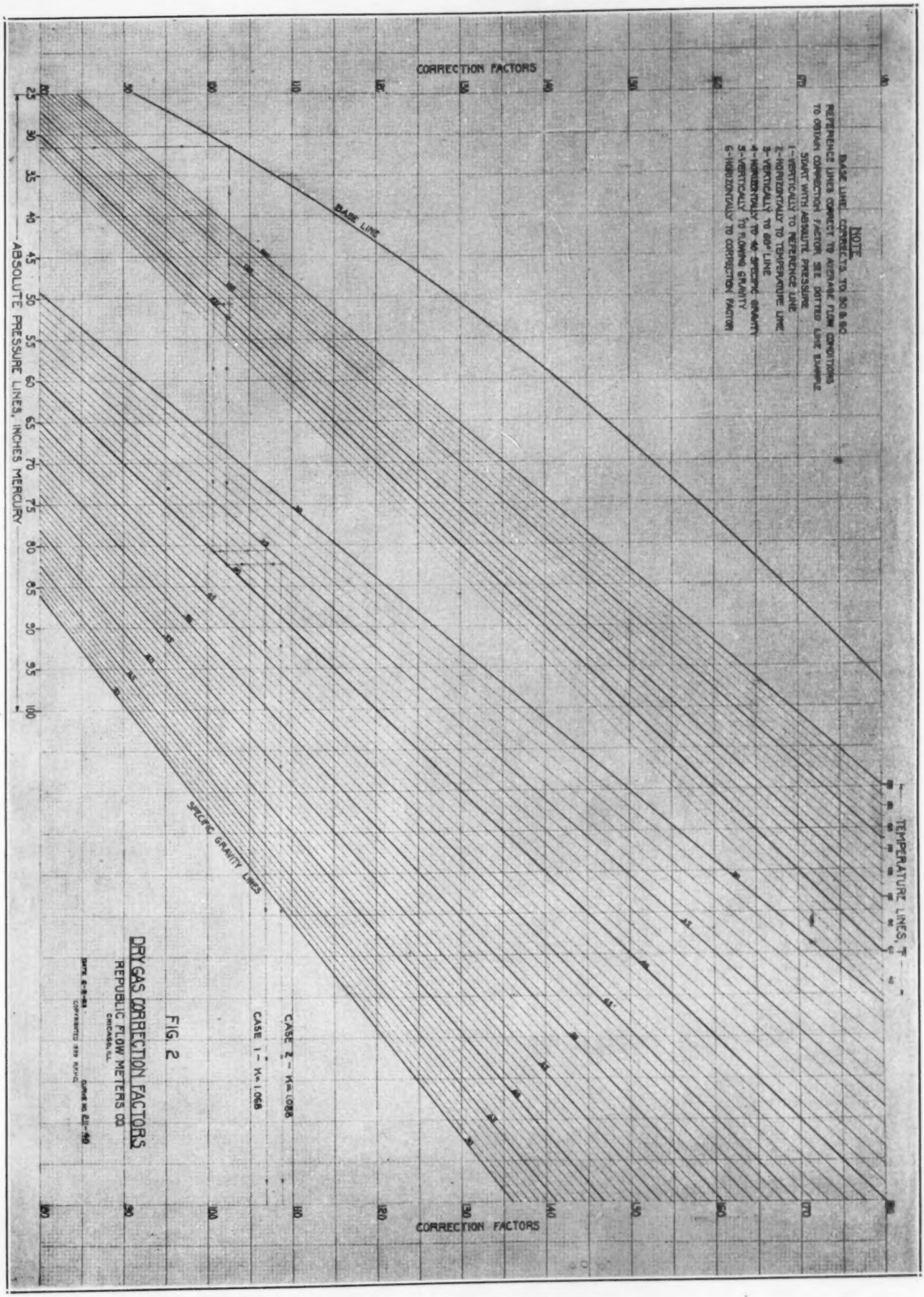
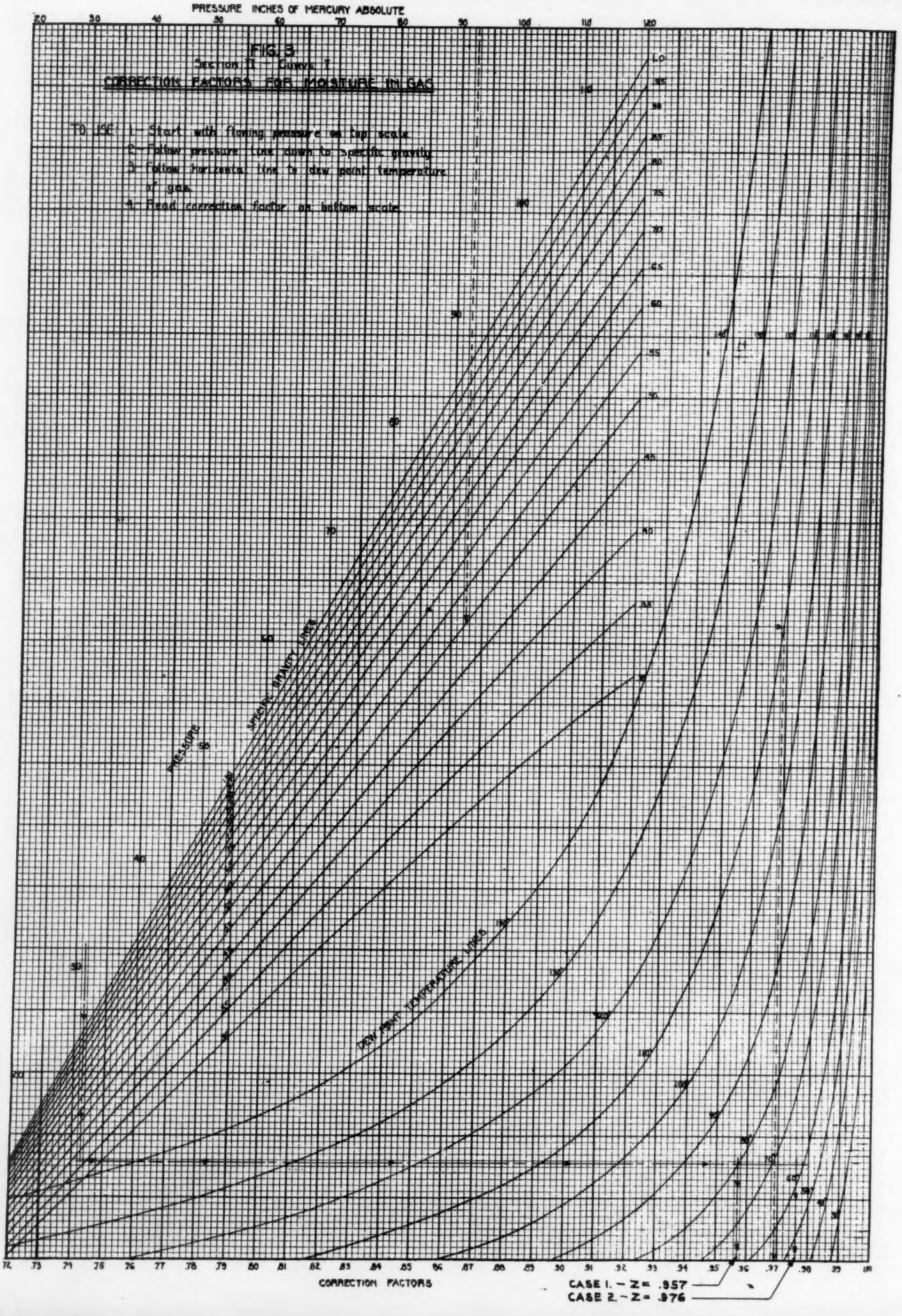

NOTE
BASE LINE CORRECTS TO 30 & 60
REFERENCE LINES CORRECT TO AVERAGE FLOW CONDITIONS
TO OBTAIN CORRECTION FACTOR SEE DOTTED LINE EXAMPLE
START WITH ABSOLUTE PRESSURE
1-VERTICALLY TO REFERENCE LINE
2-HORIZONTALLY TO TEMPERATURE LINE
3-VERTICALLY TO 60° LINE
4-HORIZONTALLY TO 40 SPECIFIC GRAVITY
5-VERTICALLY TO FLOWING GRAVITY
6-HORIZONTALLY TO CORRECTION FACTOR
CORRECTION FACTORS
BASE LINE
ABSOLUTE PRESSURE LINES, INCHES MERCURY
SPECIFIC GRAVITY LINES
TEMPERATURE LINES, °F
CASE 2 — Ha 1.088
CASE 1 — Ha 1.068
CORRECTION FACTORS

FIG. 2

DRY GAS CORRECTION FACTORS

REPUBLIC FLOW METERS CO
CHICAGO, ILL.


PRESSURE INCHES OF MERCURY ABSOLUTE
FIG. 3
Section II — Curve 1
CORRECTION FACTORS FOR MOISTURE IN GAS
TO USE: 1- Start with flowing pressure on top scale.
2- Follow pressure line down to specific gravity
3- Follow horizontal line to dew point temperature of gas.
4- Read correction factor on bottom scale
PRESSURE
SPECIFIC GRAVITY LINES
DEW POINT TEMPERATURE LINES
CORRECTION FACTORS
CASE 1. — Z = .957
CASE 2. — Z = .976

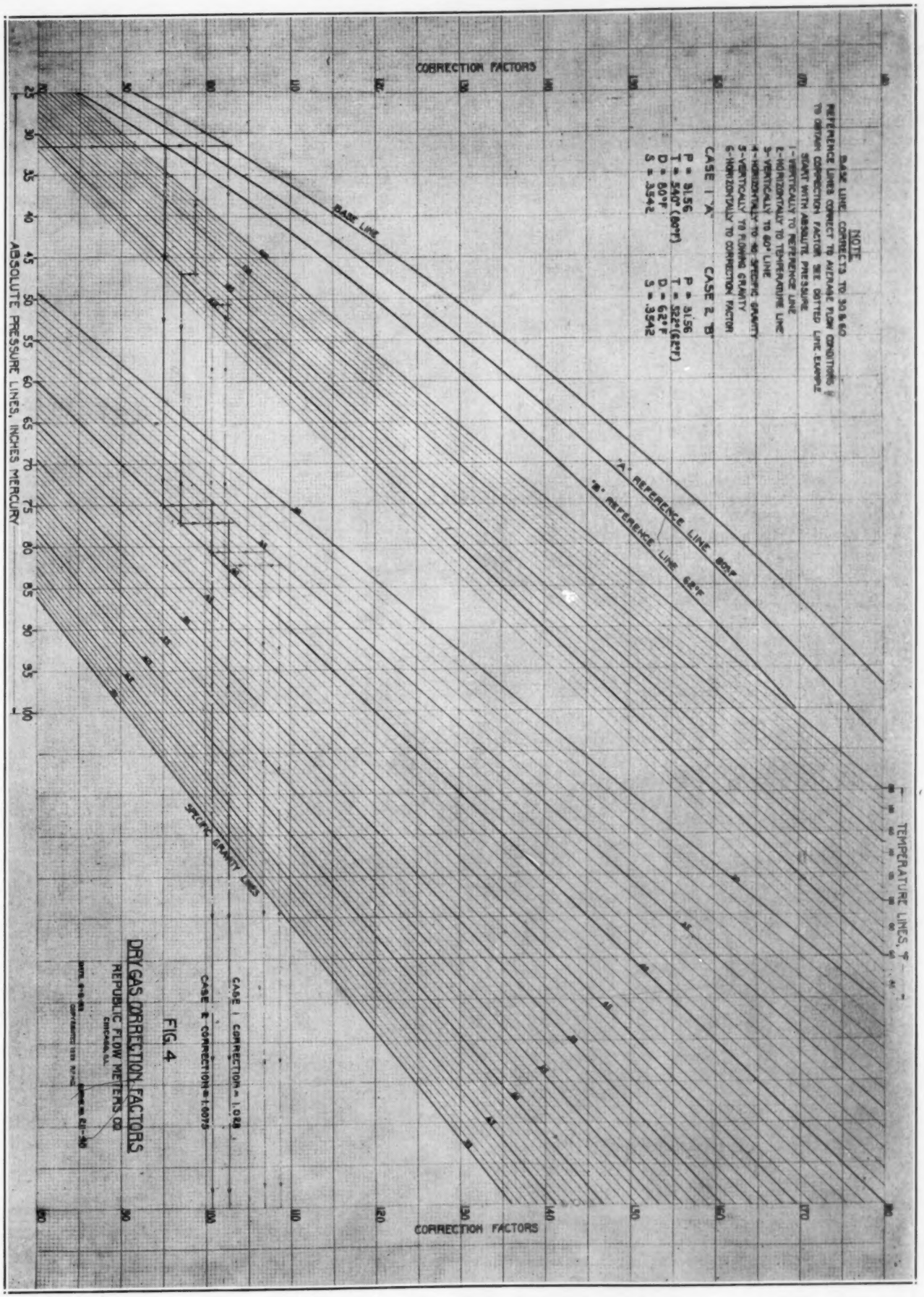


FIG. 4

DRY GAS CORRECTION FACTORS

the full determination of the quantity. When water vapor is present in the gas, the correction factor becomes the product of the two determinations.

(5) The correction for water vapor is based upon the dew point temperature of the gas or the minimum temperature which the gas reaches on its way from the ovens to the point of distribution. It is well to bring out in connection with this item that while in the majority of cases the degree of saturation under flowing conditions varies considerably, the dew point temperature of the gas is a quantity that varies but very little, especially when the gas is delivered under ground. The gas leaving the foul main is obviously saturated with water vapor because it is the vaporization of water that reduces the temperature to the point of saturation. The gas leaving this main will have a temperature of 150 degrees or over, and proceeding through the scrubbers and purifiers, it is brought down to a temperature of the water used in the scrubbers, which may be around 60 degrees in the winter time or around 80 degrees in the summer time. It is obvious that after leaving the scrubbers, the gas will drop moisture when cooled to a lower temperature, which it usually does, but it can in no way become saturated at a temperature higher than the one at which it leaves the scrubbers. For under-ground pipes, the dew point temperature is the one that the gas attains at the point where it leaves the ground. For over-head pipes the dew point temperature in the summer is usually the temperature at the outlet from the scrubbers. In the winter the dew point temperature for long over-head pipes will be very close to the temperature of the atmosphere surrounding the pipes.

Flow Measurement in Connection with Coke Oven Gas

By J. M. SPITZGLASS

Discussion

Discussed by

M. J. Conway, Combustion Engineer, Lukens Steel Company, Coatesville, Pa.

C. W. Patton, Test Engineer, Youngstown Sheet & Tube Company, Youngstown, Ohio.

J. M. Spitzglass, Vice President, Republic Flow Meters Company, Chicago, Ill.

F. E. Leahy, Combustion Engineer, Youngstown Sheet & Tube Company, Youngstown, Ohio.

P. E. Leiss, Steam Engineer, Youngstown Sheet & Tube Company, Youngstown, Ohio.

H. V. Flagg, Assistant Combustion Engineer, American Rolling Mills Company, Middletown, Ohio.

E. M. Neely, Plant Engineer, Carnegie Steel Company, Carrie Furnaces, Rankin, Pa.

W. J. Harper, Combustion Engineer, Donner Steel Company, Buffalo, N. Y.

C. P. Crist, Republic Flow Meters Company, Chicago, Ill.

C. W. Patton: I don't know that I have much to say. The paper is very interesting to me. I know we have trouble on account of poor gas, and it a matter of correction of moisture?

E. E. Leahy: Do you use these corrections which Mr. Spitzglass mentioned?

C. W. Patton: We use that correction curve for specific gravity, and pressure, and temperature, and also the saturated curve which was mentioned.

J. M. Spitzglass: Do you still use the old one, or do you use the new one?

C. W. Patton: The old one. Just the one base-line and the curve. The only place we use it is in our open hearth distribution. That is about all I have to say on that.

F. E. Leahy: Is this curve in general use now, or is it to be offered for general use?

J. M. Spitzglass: It is used in three plants: Homestead, Campbell, and Brier Hill.

P. E. Leiss: Yes, I use that correction curve on practically all my meters in the Brier Hill plant. I have found the curve very useful. In wintertime I find I have to make as much as 60 to 80 per cent corrections on all my meters, and it has worked out very well since I have been using it.

F. E Leahy: There is one test which I think is a very good test of this method. Do you have a totalizing meter and district meters that you can check against this totalizing meter, using these very corrections?

P. E. Leiss: Yes. They check out very well. I have been able to check in the summertime within 2 per cent. In the wintertime I seem to have a little more trouble. Of course I haven't got around to the point yet where I get altogether true temperature readings, but I expect to get that pretty soon, and I expect then to check out all of the time.

F. E. Leahy: One of the very interesting things in the measurement of coke oven gas is the ability to check the system, and, perhaps, we can hear some one give us that side of it.

A couple of years ago we became very much interested in this feature of measurement, and we started to investigate around through the country to find out how close they could check with their total gas to their district gas, and we found in some cases there was as much as 20 per cent difference, while

other places could check within 2 per cent or less, and invariably where they were getting close checks it apparently was due to the use of very careful calculations and measurements of their gas conditions, much as Mr. Spitzglass mentioned—pressure, temperature, and density.

H. V. Flagg: There is this one feature that occurs to me: A system of miles of pipe and possibly fifty different consumers, and fifty different meters in the system with a drop in pressure in your coke plant at the tail-end of your system, not only constant change but change in temperatures from time to time, how are you going to standardize your pressure readings on the meters so that you can have your conditions to hold all times? That is the thing that always has appealed to me as being very difficult to get the solution for, if you are going to make your distant meters balance up to them.

F. E. Leahy: What would be the necessary setup in order to get a close check, with variation in temperature conditions? In other words, in addition to a meter, what else should be provided?

J. M. Spitzglass: The ideal way would be to have a device that compensates for pressure. We are not in a business meeting, so I'll suggest that you look for a device of that kind. The next best thing would be, as is being done now, to get a pressure curve, and then take the pressures at reasonable intervals and correct for the pressure from these curves.

Now, to work one step forward, automatic devices usually follow the trend of necessity—and compensating devices follow the study of the correction. The device that will be most useful, will be the one that will correct for density, not for pressure, because pressure alone is not sufficient in all cases. In some cases you still need temperature and specific gravity corrections.

I believe, the layout of this curve has shown how all factors can be included into one reference line, and I, myself, think we are on the way to get some density compensator through the coordination of the various factors. If they can go into one line, there must be a way of putting them there, and I hope we will have it soon.

F. E. Leahy: Perhaps, Mr. Conway has had some experience along this line.

M. J. Conway: Mr. Spitzglass, as usual, has given us another masterpiece for our records. It appears to me that with a possibility of 3 per cent error, due to moisture in coke oven gas, that Mr. Spitzglass has made out a clear case for the drying of coke oven gas. For instance, a steel plant that is using approximately 10,000,000 cubic feet of coke oven gas per day at a cost of 10 cents per thousand cubic feet, a 3 per cent error represents $30.00 per day or nearly $11,000 per year. Errors of this magnitude are costly items when applied to steel plant practice.

W. J. Harper: Our checks run from 1 per cent to about 15 per cent, and some of the plants run less than a 1 per cent check with a closed system. We have temperature and pressure recorders, and keep very close check on the gas. Some of the plants will get out more than others; some more reasonable. Usually it will average 3 or 4 per cent.

E. M. Neely: I wonder if Mr. Spitzglass would care to answer a question on blast furnace gas? His discussion apparently didn't include that, but it is along the same line.

We have installed several new gas meters at our plant for blast furnace gas. We don't have the curves that he speaks of yet for our particular meters. We are using correction factors as taken out of the Republic book. Now, if we take those correction factors out of the book and use the saturated table as given in the book for those corrections—we don't have our curves, as I said before—do we then have to correct back to dry gas? In other words, do we have to multiply our quantity produced by the reciprocal of 1.0174 to get the amount of dry gas that we are actually using at the boilers, or has the meter been compensated for that in the orifice itself?

J. M. Spitzglass: I am glad Mr. Neely brought up that question. It gives me a chance to go over this troublesome point again. As I stated in the paper, I purposely brought in the factor 1.0174 into the correction to bring out the meaning of that correction. You may say I made a trial case of it so as to clear it up. The answer to the question is; if you use the correction factors from the Republic book, you obtain the number of cubic feet of gas of the standard you specified when you ordered the meter. If you wanted the meter to read in standard cubic feet of gas at 30 and 60 and free from water vapor and if you so stated when you ordered the meter, then you are getting dry standard cubic feet of gas. If, on the other hand, you did not go into that detail but you just stated the standard cubic foot of gas at 30 and 60, and at the same time you specified that the gas was saturated, then the quantity which you obtained after you made the correction is a standard cubic foot of gas at 30 and 60 and saturated with water vapor. I will repeat that; that fact has nothing to do with any correction. That is just the yardstick which was adopted when the meter was ordered. If the saturated cubic foot was adopted for the standard, you have a smaller unit and the amount will be larger. If, as in the case I demonstrated, you desire to shift afterward from the saturated to the dry standard cubic foot, your quantity has to be divided by 1.0174 or multiplied by the reciprocal of that quantity, which is .984.

E. M. Neely: This question now occurs to me: How do we know whether we have the meter for the dry gas or for the saturated gas?

Mr. Spitzglass: Mr. Neely mentioned the use of the old curves. We are trying our best to send out the new curves to the people whom we have on record. As a matter of fact ,from our standpoint, preparing this paper and presenting it here is for the purpose of bringing to your attention the use of the new curves, but the old method is just as accurate provided the gas is fully saturated. We did not include the derivation of the formula, and if any one is interested in that part and will ask for it, we will be pleased to give him a copy.

In that derivation it was shown that the old method of correction for saturated gas and the new one art theoretically the same. The only difference is that the old method was not convenient. It was necessary with that method to consider the degree of saturation at the temperature of the flowing gas while with the new formula you refer directly to the dew-

point or the minimum temperature in the line on the way from the scrubbers to the point of measurement.

One of the members suggested drying the gas in order to eliminate the large correction. I would say that if you run the gas under the ground, you have dried it in the winter time to a saturation of 40°F. and in the summer time to a saturation of 60°F. At 40° the water vapor is insignificant. You can really consider it dry. At 60° the correction for water vapor is only 1.74 per cent. Of course, the correction is never zero. There is always some water vapor present.

C. P. Crist: In the practical application of the correction curve Fig. 2, the conditions are frequently such as to bring the reference line into the temperature or specific gravity curves. For example, if the meter constant is calculated for average conditions of 25# gage pressure, 60° F. and .4 specific gravity, the divisor for the curve in Fig. 2 is 1.643, which brings the reference line into the specific gravity lines, roughly parallel to specific gravity .41. This reduces the available scale range for pressure to a minimum of about 60" of mercury absolute. Then, to obtain a correction factor from this reference line, it is necessary to go vertically to the reference line, to the left to obtain the temperature correction and back to the right to the specific gravity.

In such cases or as a general practice, it is possible to obtain the same result by a slightly different method, i. e., a constant is given for the meter, based on average conditions, assume for example 5000. Then a second constant is given, which is equal to the former divided by the divisor for the correction curve of Fig. 2. For the example previously given, the new constant would be 5000 divided by 1.643, or 3043, this constant to be used only in conjunction with the correction curve, and the correction factor from the curve to be obtained from the base line. Where no corrections are to be made, the constant of 5000 may be used.

Interconnections of Electrical Systems†

By N. E. FUNK*

I have taken for a topic tonight one you have heard a great deal of in the public and the technical press, and concerning which you may think I am rather imposing upon you to say anything; that is, interconnections of electrical systems. The reason that I picked this is not only because it has a very erroneous meaning to the lay public, but, unfortunately, to most engineers.

An article is seen in the newspapers about Chicago being hooked up with Boston. There is a great ado made of it. Unfortunately, that hookup is more academic than it is in fact. As a matter of fact, power is not transmitted from Chicago direct to Boston. The power is relayed from Chicago to a location say sixty miles away, with a generating center to hold up the voltage; relayed again to another generating center, and so passed from center to center. If one could paint the kilowatt hours blue, green and pink, for example, one would think from current descriptions that if they started out blue at Chicago, they would reach Boston of that color. As a matter of fact the blue ones never get from Chicago to Boston.

I desired to make that point because there seems to be a misconception about the economics of the possibilities of long distance transmission. In cases like the Pacific Coast, where power is primarily hydraulic, and in the mountains, the distance of transmission from the point of generation to the location of use on the seacoast is very long. The reason this is economically possible, however, is because the price of fuel is very high, and this high price of fuel makes long distance transmission entirely economic.

On the eastern seaboard where coal is depended upon for fuel, it is surprising how closely the rail cost of hauling fuel matches up with the cost of transmission by wire, the same fuel converted into electrical energy. Many of our scientific friends have been putting forth a lot of propaganda in connection with mouth of mine plants in Pennsylvania. The real story about the mouth of the mine plant is, dame nature did not see fit to locate big rivers and coal mines closely together. One must haul the coal some distance from the mines to a location which will support a large sized generating station. In most cases, it means the coal must be actually transported away from the center of use, so that a longer transmission line is required from the point at which power is generated to the center of use, than a direct line flight from the mines to the center of use. For this reason, fuel is actually transported a longer distance by rail and wire than would be the case if it were transported to the center of use by rail and a generating station located there.

Primarily, interconnection is economic for some of the following reasons: By combining two or more load centers, one is able to reduce the generating capacity necessary due to the diversity of the loads. Our company has a good example of that in the interconnection with the Pennsylvania Power & Light. The load of the P. P. & L. increases in the morning around 7 o'clock, remains practically constant during the day, reaching maximum about 12 o'clock, and at 4 o'clock falls to a light night load. Our load and the other loads of the eastern seaboard increase the same as the coal mining loads do in the morning; in the afternoon the lighting load overlaps the power load and a very sharp peak occurs. The seaboard companies are therefore able to transmit power during the daytime to the companies in the mining regions, and the mining regions can transmit power to the seaboard in the evening, when they need it. This makes an economic equation, where the cost of the interconnecting line is set up against the cost of the generating capacity saved.

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It is cheaper to develop a large station than a small one, and by interconnection it is possible for one company to add units to its system, units larger than its own demands, and take care of its neighboring company a year or two, or until the second company can install sufficient capacity to take care of its own needs, plus the growing needs of the first company, thus building up their systems with larger increments of generating capacity than they would working individually, thus making more economic construction possible.

The interconnection of load centers is not a new idea at all, although many of the present articles would lead one to believe it is. The first interconnections were made back somewhere around 1895, when the old Edison generating stations were connected together by large 220-volt D.C. cables. The purpose was exactly the same as the high capacity high voltage interconnections of today, only for shorter distances, much smaller voltages, and much lower capacities, and this same thought of interconnection has progressed as the companies have developed and as the individual company's territory has increased. Consequently, the smaller stations that have been in one section of a territory have either been abandoned, because they have grown too small to be of use in the developing of the energy needed for the community, or have continued to run as peak plants because it was economic to do so rather than replace their capacity for the short peak periods.

This interconnection scheme took place in this city when the old companies that furnished power in different sections of Philadelphia were combined into the Philadelphia Electric Company. There was a station at Susquehanna avenue and American street; one at Clearfield, near Allegheny; a little station on Race street, where the Chinamen are holding forth now; and one near Twentieth and Ranstead streets. All these were non-condensing stations, and consumed a large amount of coal per unit of output. The first step, when these companies were combined, was to put in transformers at the individual generating stations and connect them with the main generating station by transmission lines. These lines were not very long. The longest was eight miles, at 6,000 volts; illustrative of the fact that a lot of thoughts that are getting a great deal of publicity today in the way of something new are merely an old idea in somewhat different clothes.

Steel engineers have the same interest in this interconnection idea as the power companies. I believe that the time is coming (it has already arrived in some cases but not universally) where industrial plants that are either using waste process heat, or where they have use for exhaust steam in their process, will interconnect with the local electricity manufacturing companies to their mutual advantage. Where the electrical demand of the industry does not coincide with its waste heat production, or the use of exhaust steam in industrial processes, the service of the electric company and the industry's production will be so tied together that not only the industry will benefit but also the electrical producing company. The industry can then run its producing facilities where exhaust steam is the product as a reducing valve for their exhaust steam needs and let the variation of electric power be taken on the large power system. Likewise the industry that is making energy from waste heat can make its energy in accordance with its waste heat production, and pay no attention to its own load since that variation can be taken up on the large system. This is another of the uses of interconnection that is economical.

Now I think I have talked to you long enough. You have some speakers here that are much more interesting than I am, and I do not believe they will talk about a dry technical subject. I only wanted to say a few words at this time on a subject I have a great deal of interest in, and concerning which I think there is a great deal of misconception on the part, not only of the public but the engineers as well. If I have said anything that may help to put some new ideas in your mind, I am happy. I thank you.

Electrical Engineering at Lehigh University†

PROFESSOR J. W. BARKER*

I am in the position tonight similar to the freshman who just goes to college, because, as most of you know, I have just recently joined the faculty at Lehigh University, and, as the freshman always has a great tendency to consider himself well qualified to discuss matters going on at his new school, I am somewhat in that same position. I think, in the first place, we in the electrical engineering industry are particularly fortunate since our industry has grown out of science and is the child of the physical laboratory. But it is a fact that in both electrical engineering and chemical engineering the science has preceded the art. What the research workers of the past are going to be in the future is another story. They have always been a step or two ahead of the actual practicing profession. They have always given a new trend to industry. These two particular branches of engineering, electrical and chemical, have depended not upon sporadic invention, but on scientific research for their development, and the other branches of engineering, seeing the success we have made in our profession, are now attempting to follow our lead. Research has superseded invention in our profession. You might take the example of the steam engine. The theory of the steam engine was not understood for a number of years, and it was not until such chaps as Clausius, Rankine and Thomson appeared that they began to understand why this contraption did work.

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Contrast that with the electric dynamo back in the days of Faraday, and Graham and Edison bringing that out of the laboratory and putting it into practice.

As I said before, our electrical industry has depended very greatly upon this organized systematic research, be it in the educational institution, or be it in their own private laboratories, for the advancement of the art, and we have come to discard the idea of depending upon sporadic invention and have formed a closer relationship between education and our particular industry. We have also formed a habit of systematic recruiting from the engineering schools—so systematic that it sometimes bothers us. The industrial plants want to come and dig up all the graduates, and it means for a period of a couple of months class routine, as we consider it from the educational viewpoint, is somewhat seriously handicapped. The industry has taken this product of the educational institution in its raw condition; it has set up rather liberal means of enticing these novice engineers to the practicing art.

Now, gentlemen, that has had a very enormous reflection upon our method of education. The industry has felt the need of their engineers being highly trained, and, as a result, has continued their engineering education after they have left college. This action has permitted us in the educational institutions to give up a certain type of obligatory course, if you want to call it by that name, and substitute for it a rather original training in the fundamentals. This very close relationship with industry, however, has had one rather serious drawback. Industry has been so wrapped up with the idea of having clear, careful thinkers developed that they have occasionally raided the educational institutions and taken our more dynamic teachers away from us, where they can afford to pay them much higher rates than it is possible to pay them in educational institutions. Many concerns are now realizing the handicap this kind of recruiting has been to the educational institutions, and they feel by continuously recruiting among the college professors they would kill the goose that laid the golden egg. Now this tendency has given the schools a very careful inventory of what the industry wants from our graduates and we stand in the schools in exactly the same position, for instance, as the General Electric Company stands to the industrial concerns throughout the country that are using their truck. You gentlemen in the industrial plants are consuming our truck. We have something to sell. It is up to us to turn out that type of man that is in demand from the industry. If we do not, we are sadly handicapping the students that come to us expecting us to use the type of training to which they are subjected. The electrical industry has given us a closer view of their needs. They say, "Don't try to learn in college that which you can better learn when you are actively engaged in industrial work." How are we trying at Lehigh to meet these demands and specifications? The first specification which we hear from everybody is, "We want the man thoroughly trained in the fundamentals." Whether they mean essentials or not is a matter of much discussion. Let me say a word in the common accepted meaning in which you gentlemen ordinarily think of it . That means we must give these chaps a very firm foundation.

I like to think of engineering in connection with the skyscraper. The educational system can be compared very clearly to the skyscraper. During the time they are in the grade schools and even in the high school they are clearing away the ground and getting ready to do something with it. When they come to college they are getting down to bed-rock and when they leave college that structure is not a skyscraper, it is simply a skeleton, and the first few years will be spent in bricking up that structure and getting ready to make some small economic return upon the investment. I try to divide college in two parts—the first two years in geeting down to bed-rock, getting your working tools ready at Lehigh. We have set up a model so-called comprehensive examination. We tell our engineering students that during the freshmen year we will not permit them to choose their engineering course; they can simply say they want to study engineering. At the end of the freshmen year we permit them to make their choice, electrical, chemical, mechanical, etc. Of course there is always a difference between what you would like to do from a purely philosophical reason, and what is advisable to do with a student after two solid years of experimentation. At the end of the sophomore year we tell the student that he must pass an examination which will show us his ability to apply these principles of drawing, mathematics and physics. Sometimes we ask him if he came to college because when he was 11 years old he fixed a neighbor's doorbell and the man patted him on the head and told him he was going to be an electrical engineer. Many chaps do come with that idea, and it is quite difficult to knock it out of their heads. His instructor has to determine his ability to think and of his accuracy and industry.

Now this idea of a comprehensive examination has come up since you chaps were in school. I believe the comprehensive examination is a test of the ability of the student to co-relate and apply the principles of the subjects which he has taken. I do not believe for one moment it should be a memory test. I have no desire to have my chaps in electrical engineering "speck" the book; I don't give a rap for the fellow who can.

Now it is true that under the present system the comprehensive examination has a tendency to be somewhat of a memory test. We are hoping to correct that. We started this comprehensive two years ago. It is about time we hauled the thing up on the carpet and took a look at it. At the present time it consists of examinations. Now those examinations are not necessarily co-related together, nor do they pay any particular application to the principles. That is one of the things I am hoping to change. I say "I." I have just come there and have some ideas of my own. I probably am going to get some severe kicks on certain parts of my anatomy. I do not believe a memory test is the true thing. I believe if the whole library were memorized it would not do any good.

What should this comprehensive examination do for us at Lehigh? In the first place I believe it should enable the faculty to apply the ability of the students in its natural trend. It should enable the students to stick to the subjects they are making progress in, and the faculty can point out to the students their own weaknesses. It is concrete; it deals with

something roughly; it does not philosophize about the beauties of Greek architecture, but it gives the chap an opportunity to sit down and say to himself, Can I work this problem or is it beyond me? He has the ability to test himself. He should have information from them as to his progress in these fundamentals and to point out his weaknesses. It ought to enable the faculty to note particularly their adequacy in training for engineering. We ought not to sit back and say, Because Professor Soandso gives that course it must be good. Now Professor Soandso may be slipping. Professor Soandso may not be interested in engineering, he may be a pure chemist. That is the particular thing we are after. I am not berating mathematics or physics; they are essential and tools we should have in our equipment, but cut those tools down to practical use.

This comprehensive examination ought to permit earlier knowledge of the unfit. One of the problems the faculty has on its hands is in telling a boy, "You have had enough. You had better get out of here. You are wasting money." With the tuition as it is at Lehigh, $400 pretty nearly pays the student's way. As long as we have limited endowment and as long as we have limited registration, we should conserve those funds for the men who are fit to take them up. We should have the means of knowing the chap who is fit to go on, and the chap who is logically unfit for that profession. We should be able to say to the student, "It is time for you to either go to arts and science, or another school, or you should get out and work." Now we need those endowment funds if we are going to push along this research problem. I am emphasizing these points; don't think I am holding them up to ridicule and scorn; I am not. We give this examination at the end of the second year or at the beginning of the third year. It consists roughly of four three-hour examinations. I criticize that because I do not believe it gives a chap quite an adequate chance to tell us all he knows. We must necessarily, in that examination, touch the high spots. We cannot possibly cover the field adequately in that time. I believe the questions should be all mixed up. I do not believe in separate examinations in chemistry, mathematics and drawing. You can turn the thing around and mix a little chemistry in, and in that way avoid the necessity of the student cramming for this examination.

Now how should we determine these questions? Under the present system (and it is the one we just started with), each department makes up its own questions and grades its own examination. That of course necessarily eliminates the strength of the instructions given to that department. I believe the questions ought to be suggested by the engineering departments. I proposed this proposition at one of our last faculty meetings. One of the members suggested submitting the question to a committee of engineers. When I say engineers I mean professors You may not agree with me in this. My other suggestion was we spring it on the junior members of the staff, sit them down around the table and give it to them. Now, gentlemen, I mean that perfectly seriously. If the chaps who are on the staff cannot pass the examination, why give it to the students? I can imagine that some of the younger men in my department will have a good fit when they hear that.

Another thing we do not have at the present time is that the students now have no real opportunity to hear this comprehensive discussed by any member of the staff; therefore it is something to be done and gotten out of the way. There is no real interest in it except getting admission to the junior year by passing it. But I believe we ought to take that comprehensive up and spend the whole day during registration period. The Dean has made a better suggestion, and that is, after the examinations are over the comprehensive will be discussed openly, and the student shown what the solution to this or that problem may be. I was brought up in the Army and in the technical schools, and they never gave out the solution. That type of a man will come around and hear this in discussion and it ought to stimulate him to go back and look over the things in which he was weak and did not see the way to the goal at the end.

What place has laboratory work in the curriculum? I believe the laboratory is the place for testing out the theories you have learned in the textbooks. It is not a place to learn mere routine and testing of machines. The thing is to have each one of the laboratory experiments so built up that it departs from theory, and it is up to the students to find out how far.

Another thing is, when should that laboratory work come? Of course there is a great deal of discussion about that in educational circles. Should it precede the work in the classroom, or should it be coincidental with it, or should it not be co-related to it? I stand for the latter. One of the things I want to see these chaps get is a spirit of research. If we take a chap and give him a test on a shunt motor before he has ever studied it, he does not know what the thing is going to do. We should get his mind set so that he has his ideas as to just what he is going to do before he is going in the laboratory, then he goes and does it and tells us what it is all about. Therefore I say, I do not care whether the laboratory work is exactly co-related with the classroom work or not.

When I was a student they were attempting to co-relate it, and the first experiment I got was a diagram on an induction motor, and I had not had the elements of the alternating theory yet, so I sweat blood over that experiment. It took me about fifteen hours of reading before I dared sit down and write the preliminary report. I made lots of bulls in the report, and it came back with lots of red marks on it.

Another thing the laboratory ought to do is to get the student acquainted with the manipulation of the machine he is working on. I have drawn diagrams of it in the laboratory, and the only way you can do that is in the laboratory.

I have talked so far solely on what might be called the mathematical physics. You might think I am placing a great deal of emphasis on the economics in English. I picked up some reports the other day, and the subject I assigned was superpower. I grinned all over when Mr. Funk told about lights being lit in Boston from Chicago. I have never seen such rotten spelling in all my life. The English construction and the hanging together of their sentences were punk. I walked into them

hot and heavy, and told them that an engineer who does not understand English is not worth the powder to blow him up with, because, no matter how good a man he may be at the computing table, if he cannot stand on his feet and write a report, or tell somebody else about it, what good is he? I was trying to emphasize that point and make them take English in the senior year. They do not like it, but it is good for them. They have to write this paper for me and it comes in for criticism. I do not permit them to read it. I let them make notes. They have to talk for twenty minutes with just little notes in front of them, and we grade them not only on the engineering content of the paper and on the English, but on the method of standing on their feet and talking.

We are pounding home this economics matter. I illustrate the thing with an old definition of an engineer. An engineer can do for one dollar what any fool can do with two, and the dollar sign should appear in every equation they write. The man who runs away with a plausible solution, and who pays no attention to the economical side, is not a good engineer.

Now on top of all that, this chap we are turning out has got to live with the rest of the world, and we have got to emphasize somewhere in this curriculum the human element, so that he can get along with the men he is working with, as well as the boss and the men under him. We have got to give him something of the idea of living as an actual member of the corporate and civic bodies. He has got to get along with the people he lives with as well as the people he works with. To hit the line hard when he is at work, and work like the mischief when he is working. Our object is to take a boy and turn out a man. They never ought to stop studying. The man who stops studying becomes atrophied.

We don't want a man to leave Bethlehem with the idea he is a full-fledged engineer; he has only started to become an engineer. What we are trying to do at Lehigh is really trying to teach these boys to learn how to learn, and that is all.

Operation of an Open Hearth Furnace

By M. J. CONWAY*

OPEN HEARTH PRACTICE FOR THE OPEN HEARTH EMPLOYEE
LESSON NO. 2

The following lecture is one of a series which will appear in the Iron and Steel Engineer and was prepared by Mr. M. J. Conway, Combustion Engineer of the Lukens Steel Company at Coatesville, Pa. These lectures were presented before the employees of the Open Hearth Department of the Lukens Steel Company and were illustrated by a model of an Open Hearth Furnace.

It was felt that the preparation and presentation of a series of lectures of this character would bring the employee into closer touch with the design, operation and maintenance of the furnace. At the close of each lecture, the employees were invited to question the various points touched on and these questions and answers will appear at the end of the series.

The Lukens Steel Company is to be congratulated on this particular program of education of the employee.

When these lessons have been printed in the Iron and Steel Engineer the entire course will be reprinted and bound under one cover and will be available to all interested parties at a slight cost.

Preparation of the Furnace for it's First Charge. Starting a new furnace is an operation that requires a great deal of care in order to avoid injuring the brickwork and to prevent explosions where producer gas is used as fuel. The complete preparation of the furnace takes place in four stages, drying, heating, making bottom and washing. The drying is begun very slowly with a wood fire and this fire is gradually increased for twenty-four hours before oil is turned on. During the time that the wood fire is drying out the furnace the valves are usually opened on both ends of the furnace so that the stack pulls through both ends and checkers. When the oil is turned on the valves are set so that the products of combustion are led off through only one set of checkers for three of four hours, before the furnace is reversed and real heating is begun.

The flame is then reversed at regular intervals in order to heat up both checkers uniformily. When a slag-melting temperature has been reached, finely ground slag is spread over the bottom of the furnace to cover the joints between the magnesite brick and after the slag has fused the cracks shut, the making of the bottom is begun. For this purpose burned magnesite is much preferred, the procedure is about as follows:

A mixture of burned magnesite 80% to 85%, the basic cinder 15 to 20%, both ground to pass a half inch screen, is scattered over the bottom and sides of the hearth to a depth of about a half inch and allowed to sinter. At the end of about four hours another layer of the mixture is thrown in, without turning the oil off, and this procedure is repeated at the same intervals of time until the bottom is built up to the desired thickness and the banks as high as possible, which occupies about ten days in all. The tapping hole is cut out as the banks are built up and is filled up with burned dolomite, held in place by a cap of clay on the outside. The furnace is then ready for the wash heat. About 15,000 to

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20,000 pounds of basic cinder is shoveled in all over the banks and bottom and melted. This melt should be rabbled up against the banks so that every part of the hearth is made solid, and is then tapped out.

The furnace is then cooled off at least 2½ hours to allow the bottom to get hard and the cracks filled up. Burned dolomite is now piled on top of the banks as high as possible when the furnace is ready to receive its first charge.

Furnace Attendants and Their Duties. For the work on each furnace, two men are required, a first helper, a second helper and besides these there is a melter—a foreman in charge of a number of furnaces. Ordinarily the first helper has charge of the furnace except at tapping of a heat. He informs the charging machine operator of the amount of ore the charge will require and how and where to place the various parts of the charge; he regulates the heating of the furnace; directs any repairs necessary during the operation and has charge of the working of the heat, that is, making the necessary additions of ore, pig, lime etc., to prepare the steel for tapping. But when the heat is ready to tap the melter foreman takes charge. The first helper, subject to the supervision of the melter, actually taps the heat, and, after doing so, he directs the repair of the bottom and helps make up the banks.

The second helper is next in charge, he keeps a supply of dolomite, ore, lime etc., on hand and places the recarburizing additions on the platform convenient to the ladle. He helps to work the heat, digs the plug out of the tapping hole when the heat is ready to tap, keeps the tapping hole open and clean while the furnace is being rabbled and assists in making up the banks of the furnace, preparatory to recharging. He also attends to the plugging of the tapping hole, relines the steel spout after each heat and cleans around the furnace.

The necessary qualifications of a first class first helper are as follows:

Primarily he should know his furnace from A to Z, construction, design, layout of sewers, valves, air intakes, burners, in fact everything pertaining to his furnace from the top of the buckstays to the base of the stack. He should also know good combustion and how to obtain it properly, by the handling of the steam and oil, aided by the proper adjustment of the air and draught, plus the careful supervision of the furnace regenerator chambers which are under his control. To maintain the maximum efficiency and obtain the best results, the first helper must store all of the heat energy possible in his furnace checker chambers while pulling lime and getting his heat ored down and ready to tap, by carefully reducing the amount of air passing through from the air inlets so that he can open up the air valves while he is charging and melting down his charge, because in this way he can make better time, this being the most important period for time to be made. Good time can also be made by starting to work heat at the correct time and working it properly. The most time can be gained during the melting down period.

He should also keep his furnace in proper repair, the bridge walls, blocks, slopes, ports, banks and bottom, the one neglected spot which causes the most delay is bad bottom and the one causing the greatest loss of fuel and time is bad bridge walls, bad blocks and slopes. Bad bridge walls are usually caused by wrong flame direction and improper combustion.

Most bottom trouble is caused by the careless repairing or fixing of the bottom, by not properly bailing or rabbling the steel and slag out of the holes and by putting more material in at one time than will properly set solid. It is strictly up to the first helper to make the furnace bottom up right, it is also up to him to keep the metal at a safe temperature until he is ready to pull the heat, and he must get the heat in the ladle just as soon as possible after it is ready. A good first helper knows that there are about five things that will cause a furnace roof or walls to burn, namely; an empty furnace, scrap melted, smooth and shiny a heavy coat of lime, metal too hot or careless setting of burners, therefore, the first helpers duty is to watch that any furnace delay beyond his control does not cause the furnace brickwork to be punished because he is not doing his part. He will watch his furnace every minute and will watch for everything that will work to his advantage, such as the composition of his charge, the way it is charged, the percentage of pig and scrap, the melting down of the scrap so as not to over oxidize the charge and cause soft melts, shutting down until there is more scrap in sight. He will attend to all this to conserve fuel, he will also watch the second helper that he makes the joint and spout properly so that it will safely carry the product of the furnace into the ladle.

Last, but not least, he will at all times be trying to prepare himself for the job higher up and in so doing he will make himself a better man both for his foreman and his employer. A first helper needs only the opportunity to be able to do a melting job, because confidence, an essential qualification, goes hand in hand with efficiency and this he should already have.

The melter or foreman has charge of a group of six or seven furnaces.

He takes charge of any furnace in his group when any serious difficulty arises and he always has charge of the tapping of the heat. He receives an order for the kind of steel desired from the steel distributor, so when the tapping time of a heat is near he orders the recarburizers and takes charge of the furnace when the carbon is but a few points above the tapping point. He decides when the heat is ready, gives the order to tap and directs the addition of the recarburizers, etc. He gives the order for the lifting of the ladle when the steel is out of the furnace and inspects the bottom of the furnace after the heat is out.

Duties of a Good Melter Foreman.

1—He must be willing and anxious to add to his store of knowledge about his job.

2—He must be able to transfer his knowledge to the men under him.

3—He must cultivate personality in order to make his men have faith in him, making them willingly do their utmost for him 480 minutes a day.

4—He must be able to make each man realize his duty to the foreman, to himself, and his Company and teach his men that the best way to obtain help is to help themselves, for men that

do this have no trouble obtaining assistance from anyone above them, or anyone having the knowledge which they seek.

5—He must know good combustion and how to obtain and maintain it constantly, and be able to teach his first helper to know good combustion.

6—He will watch and compel the men under him to watch, the mix going into the furnaces to prevent excessive high and low melts which consume time, fuel and unnecessary labor, and expense and a loss to himself, his men and his company.

7—He must know how to get a heat in the best possible shape, by having the best slag conditions, and should be able to convey to the men under him this knowledge, and firmly encourage them to get the heat in that condition. He is hired to instruct and see that his instructions are obeyed, not to do the work himself.

8—He will positively demand that his helpers run the metal on the cool side until the heat is in shape, allowing only a reasonable time to get the heat hot and tapped will not cause so many holes and bad bottoms.

9—He will impress on his men the price they have to pay in dollars and cents for all delays which they can prevent themselves. He should also watch his operation to obtain the maximum tons per furnace hour.

10—He will never hesitate to ask his superior for any information or help that will improve himself, his men or his company.

11—He will not allow his men to loaf in another department nor will he allow men from other departments to loaf in his department.

12—He will plan his work ahead so as to eliminate all delays possible in charging and tapping his furnaces.

13—He will always have a man ready to take his or another man's place so that the efficiency of his department will not suffer.

14—He will always watch the work of his men closely and promote them according to their ability and not because of personal reasons.

15—His biggest job as well as that of his superior's is to cause the men to think and use their brains. He should not be afraid to take, seek or give help when called upon to do so. That is the way we all advance our positions, and asking a question does not exhibit a dull or stupid character, but, to do something wrong for the sake of asking advice does.

SUMMARY—Know yourself, know your men, know your job, know your men's job, for to be a successful foreman you need these qualifications. This applies to all foremen.

Order of Charging. The order of charging the raw material is as follows: The limestone is charged first for several reasons; If it were charged on top of the scrap, for example, it would act as an insulator and thus prolong the melting period and the benefits to be derived from the lime boil would be lost. The scrap is next charged, and if cold pig iron is used, it is charged with the scrap. The gas or oil which is usually but partly turned on during the charging is then turned on in full and the first or melting stage begins. If hot metal is to be charged, it is not added until the melting period is well advanced. Heat is imparted to the charge, partly through radiation from the incandescent particles in the flame. The fuel should therefore, burn with a full long flame, reaching almost from end to end of the furnace, but the flame should never extend through the ports and down takes as it would then rapidly fuse the brick of those flues and waste the fuel. For the same reason, the flame should be directed downward from the port and not be allowed to impinge on the roof. The light scrap and pig iron begin to melt first. During the melting, much of these materials is oxidized, so that there is formed both molten metal and oxides, which trickle down over the scrap to the bottom. Reversals of the flame should occur every fifteen to twenty minutes during this period, if the checkers are hot, and care must be taken not to overheat the roof, for too high temperatures will cause the bricks in a new roof to spall and those in an old one to fuse. Silica brick frequently sweat, that is, fuse slightly, but this condition does no harm and indicates a favorable temperature in the furnace.

Burnt lime-stone is used at times instead of raw stone, depending on the price of pig iron and scrap, as burnt lime allows a much lower percentage of pig iron to be used because there is not the carbon reducing agencies in burnt lime that there are in raw stone, such as carbon dioxide gas and moisture, which have been eliminated by burning. The furnace should be charged and operated in the following manner: When using burnt lime, first the bottom should be thoroughly covered with pig iron to prevent lime sticking to bottom, 20% of the total iron charged is sufficient to cover the bottom. If the charging machine man does his part right and the first helper carefully supervises the charging, there should be no excuse for bottoms building up. When charging, two pans of burnt lime from the total charge should be put on the stand, so that at any time the metal starts to foam an additional pan or two of burnt lime can be put in if necessary, which will in most cases stop the foaming, on the other hand if good scrap and pig iron have been charged there may be plenty of lime to take care of this without using the two pans set aside, thereby saving the cost of the two pans of burnt lime, in addition to getting the heat melted and lime up much quicker.

In cases where back and front walls have been repaired or a roof patched all the lime should be charged and if a quantity of brick have been left in the furnace, extra lime should be charged. In cases where heats melt high and slag is thin, raw lime-stone should be used because it is cheaper and has a tendency to reduce carbon in the bath, eliminating the use of so much ore, which further thins the slag.

Care is always taken with the first few heats on a new furnace, until the brickwork has thoroughly seasoned and until full working temperatures are attained.

The lime boil is characterized by a rising of the lime to the top of the bath, and by a violent bubbling of the bath caused by the rapid evolution of the carbon dioxide gas from the undecomposed limestone which still remains on the bottom and also in part by the continued oxidization of carbon in the molten metal. These activities play important parts in the

process. Thus not only does the violet bubbling, caused by the evolution of the carbon dioxide gas, agitate the metal and slag, thus mixing them and exposing the metal to the oxidizing influence of the flame, but part of the gas, at least, unites directly or indirectly with the carbon remaining in the iron to form carbon monoxide. Furthermore, by rising to the surface the lime may replace iron and manganese oxides in the phosphates, sulphates and silicates present and thus become part of the slag while any excess lime is also taken up and goes to increase the basicity of the slag. This property of the slag makes it more capable of retaining both the phosphoric and silicic acids together and renders the former less liable to be reduced. During this period the flame in the furnace should be reversed frequently in order that the temperature of the bath eventually will be well above the melting point of the decarbonized metal.

The Working Period. Since all of the impurities except carbon have now been eliminated the operations during this period aim at regulating the properties of the slag, adjusting the carbon content of the steel, and raising the temperature of the bath to the point where the steel may be tapped from the furnace. In order for the steel to be poured without difficulty this temperature should be at least 300 degrees fahr. above its fusion point. Both the chemical and physical properties of the slag play most important parts in the basic process. In order that it may protect the metal against contamination by sulphur from the flame, retain the impurities especially phosphorus, and promote the elimination of the carbon, the slag must contain a large quantity of oxidizing agents, except at the end of the period and must be strongly basic at all times, but even with the chemical composition of the slag properly adjusted, it's activity will depend upon the fluidity to a great extent. The reagents at the disposal of the operator for regulating those properties are iron oxide, limestone, dolomite and fluor-spar. The iron oxide is usually in the form of lump ore, though heating furnace cinder formed on a magnesite bottom may be used.

There are two general methods of working heats as follows: The first method is somewhat like the Bessemer, that is, the carbon content of all heats is reduced to a common point, about .10% when the steel will be tapped and the percent of carbon will be raised to that desired by the additions of the recarburizers. In the second method the carbon is caught on the way down, that is, the carbon content is reduced to a point slightly under that required to allow for the carbon contained in various additions, and the bath of steel is then tapped. Medium and low carbon steels are usually worked by the first method, while high carbon steels may be worked by either method.

For judging the temperature of the bath, two very simple tests are employed by the furnace men. One of these tests consists of quickly inserting the end of a long steel bar or rod into the bath of metal and slowly moving it from side to side until the part immersed in the metal melts off. Then the bar is withdrawn, and from the appearance of the bar and the conditions of the bath with respect to temperature may be judged. Thus if the bath is too cold, the end of the rod will pointed, if too hot, it will show nicks on the sides near the end, but if the temperature is right, the end of the rod will have melted off so as to leave a clean square end. The second method depends upon the quite evident fact that the higher the temperature of a fluid the longer it will remain fluid in contact with cold surroundings. It is carried out simply by quickly withdrawing a test spoonful of the molten steel from the bath and at once pouring it, rather slowly, but at a fixed rate of flow, out of the spoon. The operator judges the temperature of the steel by the way it flows, and by the extent and thickness of the skull it leaves in the spoon. By long practice with these methods the workmen become very expert in making these relative determinations of temperatures.

The furnace is usually so manipulated so that the tapping temperature is reached before the carbon content has been reduced to the tapping point. To accomplish the tapping, the second helper digs out from the rear the mud plug and most of the dolomite with which the tapping hole is closed, after which the hole is opened by driving outward the remaining dolomite by inserting a bar through the wicket of the center door in the front of the furnace. The steel then flows through the hole out of the furnace and down the spout into the ladle. Since the tapping hole is on a level with the bottom of the hearth, the greater part of the steel is out of the furnace before any slag appears, and this fact permits the recarburization in the ladle. It is not advisable for the recarburizing materials to be allowed to come into contact with the slag, since some of the phosphoric acid in the slag may be reduced and the phosphorus reenter the steel. The tapping spout and ladle should be so placed as to direct the stream of molten metal a little to one side of the center of the ladle, as the swirling motion tends to mix and make more homogeneous the contents of the ladle.

After the runner has been lifted from the furnace and the hearth drained, the second helper cleans out the tapping hole, and again closes it with dolomite and caps it with clay. The banks which have been cut away by the slag from the heat just out are repaired by throwing dolomite on them and the furnace is then ready for charging again.

In the operation of a furnace, troubles of very serious nature may occur at any time, unless the furnace is watched closely and carefully handled. The tap hole may break out prematurely if it is not properly tamped and capped, or, it may become hopelessly clogged if it is not properly cleaned after each heat.

The ports require constant attention to prevent them from building up or melting down, and thus changing the angle of the flame, which would tend to overheat some part of the furnace and would be less effective in heating the bath. The most disasterous mishap that can occur to a furnace is a break out. Break outs may be caused by several things. A hole near the bank may not have been noticed, or may have been insufficiently repaired, in which case, the steel works down into it and gradually makes it deeper, until, finally, the metal finds its way through the wall and out of the furnace. Once a break out occurs, the tapping hole should be opened immediately, and as much as possible of the steel gotten into the ladle or cinder pit. The spread

of cinder and metal upon the floor where the break out has occurred can be limited usually by throwing dolomite around it.

Repair Materials. It is evident that for making up the bottom and for doing repair work about the furnace much depends upon the materials employed. Great care must always be exercised to see that they are of the right chemical composition and best suited for the work in hand, as otherwise, the best workmanship in making the repairs will go for naught.

Developments in Control

By W. H. WILLIAMS*

During the year 1929, many new developments were introduced by the Clark Controller Company which have been enthusiastically received by the steel mill industry and have materially added to the already successful line of manual and magnetic controllers and accessories.

Magnetic controllers, which are now in their third year of production, have received much attention during the extensive development program and, as a result, several new sizes of contactors have been added

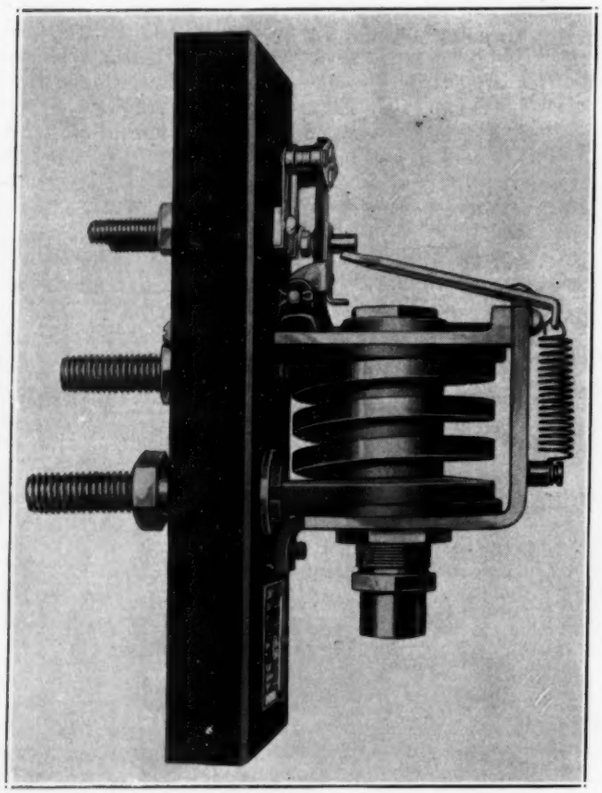

FIG. 1.

to the group. These new sizes include both the straight shunt contactors and the time limit acceleration contactors, together with the modified types which include the spring closed and double end designs. These new additions bring the total to six different sizes which will meet the requirements of the majority of applications.

*Vice President, Clark Controller Co., Cleveland, Ohio.

Another of the year's developments was the Type L Overload Relay. This unit not only is an important step in connection with magnetic controllers, but also in the manual control field. The principal of this overload relay involves the use of the same type of hermetically sealed dashpot as is used in the time limit acceleration contactors, which produces an excellent combination of inverse time limit and instantaneous trip for all overload conditions. This new overload relay is shown in Fig. 1. The illustration is a side view of the relay without the protective aluminum cover. It is made in either the automatic or hand reset type.

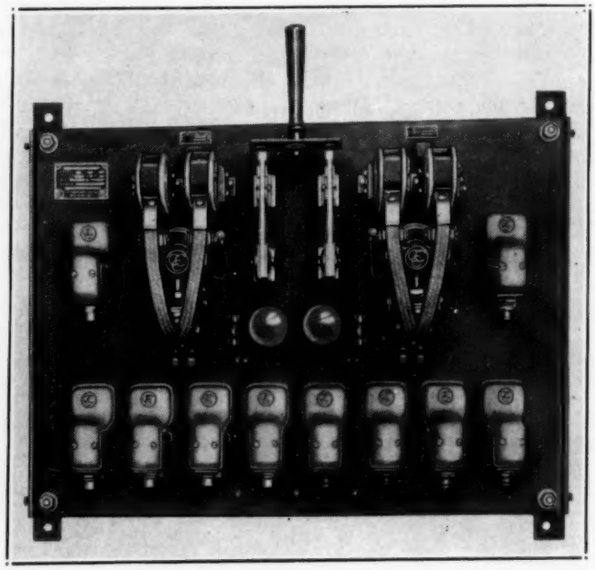

FIG. 2.

The past year's developments have also included other types of relays which were placed on a production basis several months ago. Among these are the Plugging Relay, the Shunt Field Protective Relay, the Field Acceleration or Field Vibrating Relay and the Timing Relay. All of these are important additions to various types of industrial and steel mill control equipments.

A development of interest to all crane users is the Crane Protective Panel, which made its debut during the past year. A representative photograph (Fig. 2) is shown with one of these panels from which the cover has been removed. This cover is so arranged that the knife switch controlling the main circuit may

be operated without removing the case. This particular design incorporates the new double pole main line contactors and the new Type L overload relays. It is a five circuit type with double overload protection.

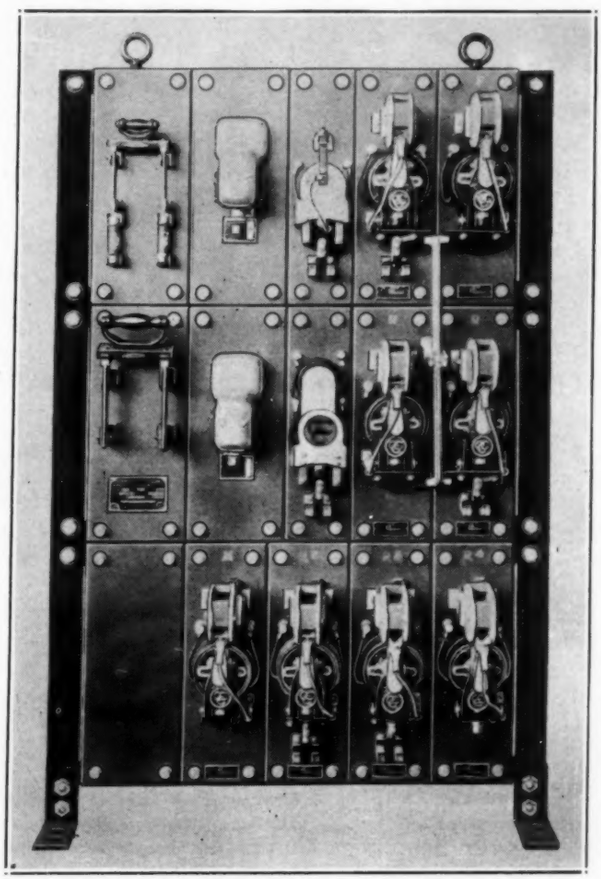

FIG. 3.

A large number of magnetic control equipments were built during the year 1929. Many of these were designed with special arrangement to meet the various conditions in the operating field, while others were of more or less standard arrangements. A typical example of the standard reversing plugging magnetic control board is shown herewith in Fig. 3. This equipment consists of four Type CD shunt contactors for reversing, which are mechanically interlocked; one type CD negative line or main line contactor for opening the side of the line opposite to that of the reversing contactors; three Type VT vari-time accelerating contactors; one no-voltage protective relay; a plugging relay; two Type L overload relays (one for inverse time operation and one for instantaneous operation on excessive overloads); a double pole main line knife switch and a fused control circuit knife switch which may be used for testing the equipment without operating the motor.

Our engineers, during the same year, achieved another success in a new scheme of dynamic lowering magnetic controller for crane hoist application. The control scheme features a unit which makes use of a minimum number of contactors and a comparatively small amount of resistors, but incorporates all the desirable features of high speed lowering of light hook with a safe lowering speed at full load. An additional automatic feature has recently been added which provides graduated dynamic braking when the master switch is brought to the "off" position.

For several years past the trend of development work on magnetic control equipments has been towards the definite time principle of acceleration, the improved arc handling ability of the contactors and the general simplification of the entire rear of panel wiring. These points have been emphasized by all manufacturers of magnetic control equipments. During the past two years of service, results have borne out the contention that the elimination of accelerating relays in the Clark Vari-time Accelerating Contactors has not only decreased the number of units on a control board and materially simplified the wiring on the rear of it, but also has improved acceleration under all conditions.

Not only has our development program extended to the magnetic control apparatus, but also to the manual controller field. The result is, a new design of dynamic lowering crane hoist controller. This unit has taken its place in the field and in addition to its operating characteristics has a mechanical design which is a departure from previous construction. The contact arm is of the three arm spider type and gives perfect balance for the operator. The arrangement of the contacts on the slate face is also changed to conform to the new contact arm design.

Items of Interest

PERSONNEL CHANGES

R. J. Harry, who for 25 years has been with the Carnegie Steel Company at Homestead, later as assistant superintendent of the Electrical Department, has resigned his position to become general sales engineer with The Alliance Machine Company at Alliance, Ohio.

Ralph R. Newquist has been appointed sales engineer of the Chicago office of the Reliance Electric and Engineering Company, Cleveland, manufacturers of alternating and direct-current motors.

The Surface Combustion Company of Toledo announces that, effective May 1, the Pittsburgh branch of the company and the offices of the Mantle Recuperator Division will be consolidated and will occupy new offices at 617-619 Henry W. Oliver Building.

WITH THE MANUFACTURERS

A new single pole pressure regulator, exceptionally small in size, is announced by Cutler-Hammer, Inc., 157 Twelfth street, Milwaukee, Wis. This new device, designated as Bulletin 10006, can be used as

a starting switch for motors up to one horsepower, 230 volts, A.C. or D.C., or as a pilot switch in the control circuit of automatic starters for larger motors. The regulator closes the circuit at low pressure and opens the circuit at high pressure. It can be adjusted to open the circuit at any pressure from 30 to 200 pounds.

Steel strip is rolled so fast at the Sharon Steel Hoop Company, Sharon, Pa., that one end of the strip is in the shipping room before the other end is out of the furnace. This is one of the highest-speed strip rolling mills in this country, and incorporates many new methods and much improved equipment. As a result, the product is improved and production costs are decreased. The mill is entirely electric in operation, the equipment for which, aggregating the equivalent of 45,000 horsepower, having been furnished by the General Electric Company.

One of the novelties in the plant is the use of a modified public address system, with a microphone and loud speaker, by means of which the men on the rolling floor deliver instructions regarding operations and speed changes to the operator in the control "pulpit". This method of communication was adopted to facilitate high speed, keeping the pulpit operator in constant and immediate audible contact with the work he controls. He can see these operations through the glass sides of the pulpit which is mounted in an elevated position overlooking the rolling floor.

The machinery at Sharon rolls strip at a maximum speed of 2400 feet per minute, or around 26 to 27 miles per hour. The steel enters the mill with a length of 30 feet, and is rolled to a length of from 1500 to 1800 feet, the thickness being greatly reduced during the process. When its final thickness is reached—all in the space of a few seconds—the long strip flashes from the rolls, white hot and at high speed, and is led through serpentine convolutions to conserve space in cooling.

The various types of product handled require a range of speed varying from one-fourth to full speed. Throughout this wide range the speed relations of the 12 major rolling mill motors are held to within 1/10 of 1%. This precise control is accomplished by means of an ingenious General Electric regulating system which operates without attention on the part of the pulpit operator.

The six stands where the product receives the finishing processes are driven by individual motors all mounted on a single base and having an aggregate output of 7500 horsepower. Space requirements and the desirability of duplicate design in widely varying ratings resulted in a unique arrangement of double and single-armature motors, making all individual parts practically duplicates.

The roughing mill motor is the largest used in the strip mill and is rated 4500 horsepower. It operates at speeds of from 150 to 450 r.p.m. It is one of the largest motors used in such service in this country and is 21 feet long, weighs 221,000 pounds and has a rotating shaft 24 inches in diameter.

Arc welding is being used on many of the new buildings now being constructed. Among the new projects is the 3000-ton office building of the Southern California Edison Company which will be 80% welded, a 15-story, 1600-ton office building of the Boston Edison Company which will be field welded and five new welded buildings for Westinghouse all of these projects reflect engineering and public confidence in welded structure. A recent survey disclosed these pertinent facts:

105 cities permit welded building construction.
70 buildings have used arc welding in erection.
2 railroad bridges are all-welded.
Welding costs less.

Industrial engineers are awakening to the fact that welding is a new and potent tool.

Four years ago Westinghouse started campaigning for official sanction of welded building construction in cities. Today over a hundred cities and towns have either adapted regulations under which welding can be done or have allowed welding to be used on buildings within their jurisdiction. In an art as young as electric welding, such rapid progress is remarkable.

In practically fifty cities scattered over 18 states, electric welding has been used in the construction of about 70 structures. A code for welding in building construction, issued last year by the American Welding Society, is paving the way for more and more cities to safely permit this type of construction.

Crocker Wheeler Electric Manufacturing Company of Ampere, N. J., are distributing a folder on "Direct Current Adjustable Speed Motors." Copy may be had on request.

OBITUARIES

Elmer T. McCleary, president of the Republic Steel Corporation, died at a Youngstown hospital suddenly on April 22, following an operation. Since 1928, Mr. McCleary had been president of the former Republic Iron and Steel Company, succeeding Thomas J. Bray.

Mr. McCleary was born in 1879 and attended school at Harrisburg, Pa. He graduated from Penn State College as a metallurgist and after graduation was with the Diamond State Steel Company of Wilmington, Del. From there he went to Ohio Works as metallurgist of Carnegie Steel Company, Youngstown, O.

In 1906, Mr. McCleary went with Youngstown Sheet and Tube Company as chief chemist. For 22 years he was with this company and advanced rapidly. In 1924 he was elected assistant vice president. In 1926 he was elected vice president holding this office for two years. During that time with W. C. Reilly, senior vice president in charge of operations, Mr. McCleary managed all plants of the Youngstown Sheet and Tube Company.

In 1928, Mr. McCleary was elected president of Republic Iron and Steel Company, and with the organization of the Republic Steel Corporation he became its head.

In the death of Mr. McCleary, the Association of Iron and Steel Electrical Engineers feel that they have lost a friend. Mr. McCleary was always active in the Association's activities and was always ready and willing to lend his time and efforts for better engineering in the Iron and Steel Industry.

LIST OF EXHIBITORS
AT
Iron and Steel Exposition
BROADWAY AUDITORIUM BUFFALO, N. Y.
JUNE 16 - 17 - 18 - 19 - 20, 1930

Exhibitor	Booth No.
Aluminum Co. of America	168–169–170–188–189–190
Alliance Machine Company	51
Allis-Chalmers Mfg. Company	81–82
American Air Filter Co., Inc.	146–147
American Engineeering Company	5
American Manganese Bronze Co.	198-199
Appleton Electiic Company	103–104
Atlas Car & Manufacturing Co.	25–26–27
Automatic Reclosing Circuit Breaker Company	7
Bailey Meter Company	163
Baker-Raulang Company	177–197
Bartlett-Hayward Company	154
Benjamin Electric Mfg. Co.	63–64
Botfield Refractories Co.	178
Bristol Company	56–57
Brown Instrument Company	78
Bull Dog Electric Products Co.	95
Burroughs & Lydon, Inc.	185
Burndy Engineering Company	133–153
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Century Electric Co.	62
Chisholm-Moore Hoist Corp. (Columbus-McKinnon Chain Corp.)	117
Clarage Fan Company	127
Clark Controller Company	86–87–106–107
Cleveland Crane & Engrg. Co.	75–76
Cleveland Worm & Gear Co.	164
Cling-Surface Company	98
Colts Patent Fire Arms Mfg. Company	10
Condit Electric Mfg. Company	46
R. W. Cramer & Company, Inc.	155
Crocker-Wheeler Electric Mfg. Company	91–111
Crouse-Hinds Company	71–72
Cutler-Hammer, Inc.	141–142
Delta Star Electric Co.	45
M. H. Detrick Company	30
Joseph Dixon Crucible Co.	38
Edison Storage Battery Co.	137
Electric Controller & Mfg. Co.	49–50–69–70
Electrical Engineers Equipment Co.	185
Electric Machinery Mfg. Co.	88–108
Electric Power Equipment Corp.	84
Electric Service Supplies Co.	55
Erie Malleable Iron Co.	114
Erie Steel Construction Co.	1
Fafnir Bearings Company	289
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D. B. Flower Manufacturing Co.	77
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Leeds & Northrup Company	283–284
Lincoln Electric Co.	99–100–119–120
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Manning, Maxwell & Moore, Inc.	20
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Morgan Engineering Co.	149-150
Morse Chain Company	68
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National Carbon Company	128
National Electric Products Company	121–122–123–124
National Safety Council	8
New Departure Mfg. Co.	158–159
Norma-Hoffman Bearings Corp.	73
Nichols-Lintern Co.	53–54
North American Fuel Co.	179
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Ohio Electric Mfg. Co.	112
Okonite Company	47
Orange Roller Bearing Co.	4
Otis Elevator Company	42–43
Pennsylvania Lubricating Co.	134–135
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Stearns-Stafford Roller Bearing Company	145
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Texas Company	102
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Transmission Ball Bearing Co.	39
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Union Wire Die Corporation	220
United Engineering & Foundry Co.	291
U. S. Graphite Company	65
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V. V. Fittings Co.	180
Westinghouse Electric & Manufacturing Co.	171-172-173-174-175-176-191-192-193-194-195-196-191A-192A-193A-194A-195A-196A.
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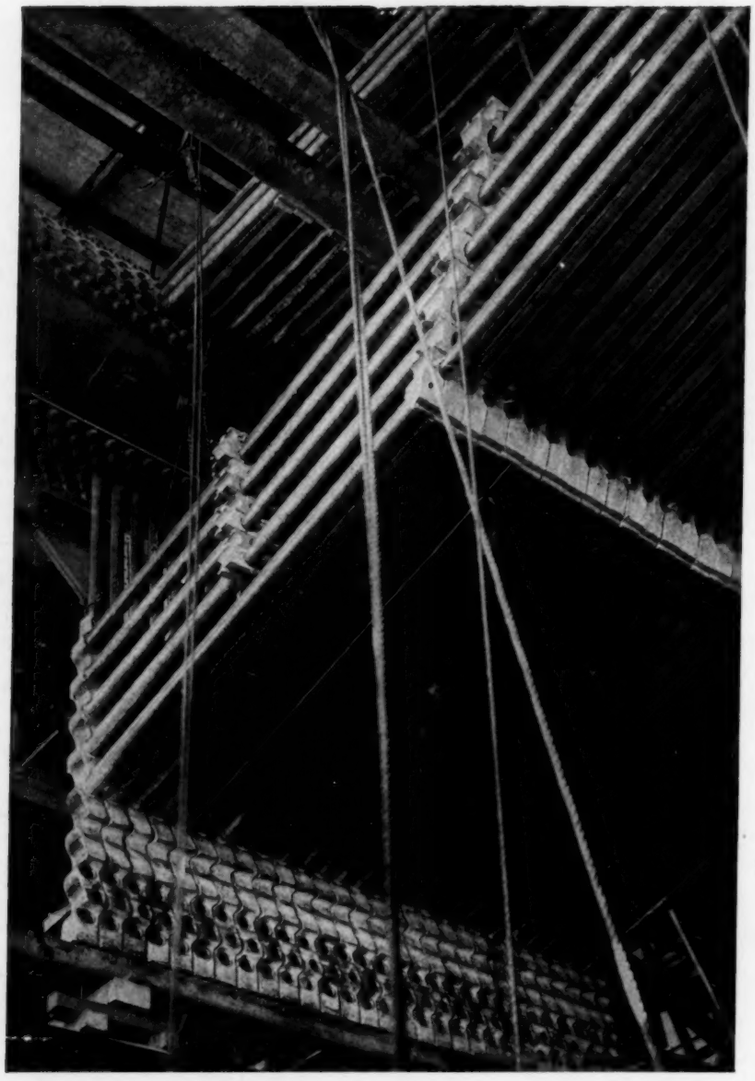
Edwin L. Wiegand Company	113
L. J. Wing Mfg. Company	101
Wire & Wire Products	221
Daniel Woodhead Company	74
Wright Hibbard Industrial Electric Truck Corp.	186–187
Yale & Towne Mfg. Company	59–60–79–80

Walsh & Weidner Boilers
at Great Western Power Co.



These oil fired boilers, designed to operate at 450 lb. pressure, are among the largest on the Pacific coast.

5,000,000 lb. of steam per hour is the aggregate capacity of Walsh & Weidner Sectional Header boilers sold in 1929.

COMBUSTION ENGINEERING CORPORATION

200 Madison Avenue **New York, N. Y.**

BOILERS - STOKERS - PULVERIZED FUEL EQUIPMENT - WATER-COOLED FURNACES